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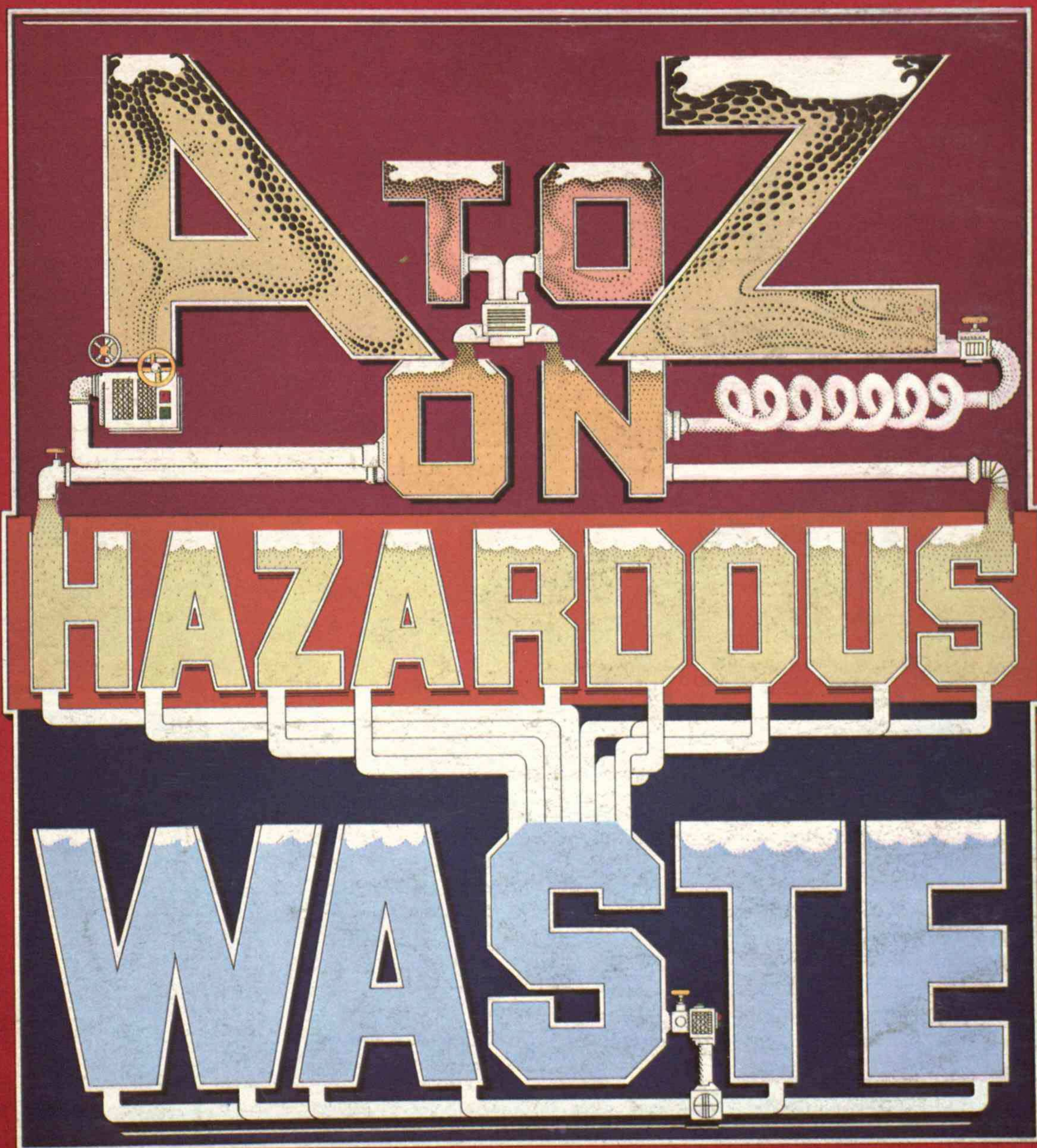

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Technology Review

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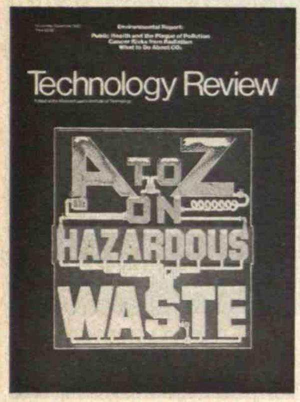

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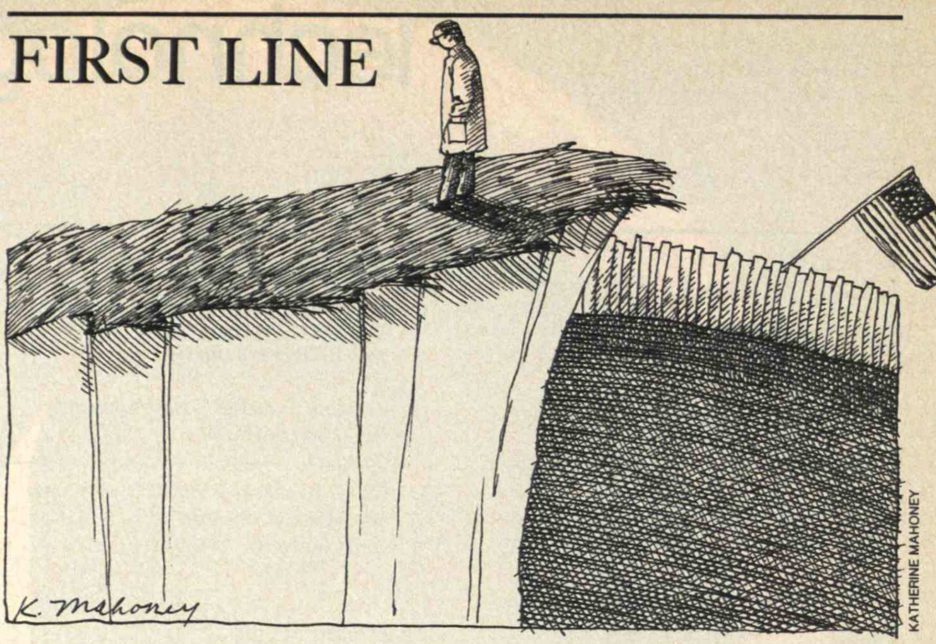

KATHERINE MAHONEY

Leading Technology vs. Keeping It at Home

If U.S. technological superiority is in jeopardy from foreign entrepreneurs who capitalize on our own innovations, why not simply clamp down on outflows of our technology to foreign competitors?

Protectionism is a tempting but simplistic response to any situation where the competition seems to be gaining the upper hand. But restrictions on exports of U.S. technology are a dangerous, two-edged sword with both edges pointed in the wrong direction:

☐ Screens and filters on U.S. technology, however well-meaning, can only dampen the key incentives—the prospects for human betterment and expectations for financial gain—that motivate our technical innovators.

☐ Fences breed fences: our access to foreign technology (on which we may well be better positioned to capitalize than its inventors) is likely to be restricted in retaliation for any overzealous constraints we impose on the flow of our own.

As the use of export controls widens, the potential for mischief increases. Concerned by recent proposals to sharpen the interpretation of U.S. regulations on international traffic in our technology, the presidents of five of America's major research universities wrote to the secretaries of the Departments of Commerce, State, and Defense early this year to protest restraints on research publications, discourse among scholars, and admission of students and visiting scholars. The new proposals would apply to broad scientific and technical areas, including very high speed integrated circuits (the key to new developments in missile guidance, computation, and communication) and cryptography (a challenging outgrowth of modern mathematics).

"Restricting the free flow of information among scientists and engineers," wrote the five presidents, "would alter fundamentally the system that produced the scientific and technological lead the government is now trying to protect and leave us with nothing to protect in the very near future."

In their replies, the secretaries of the Departments of State and Commerce were far from reassuring to President Donald Kennedy of Stanford and his four colleagues (Marvin L. Goldberger of Caltech, Paul E. Gray of M.I.T., Frank H.T. Rhodes of Cornell, and David B. Saxon of the University of California). The substantive issue, they say, is whether the the technical data provided to foreign persons are important to our national interest. Government approval will be required before data "directly and significantly related to industrial processes" and "not generally available to the public, . . . [i.e.] not in the public domain," can be sent to the Soviet Union, the Warsaw Pact countries, and the People's Republic of China.

A far different approach has been suggested by Thane Gustafson of Rand Corp., an organization not unfamiliar with the need we all accept, at least in part, for secrecy in defense technology: "The transfer of technology depends less on the fact that knowledge and skills have been divulged than on the fact that the receiver knew how to make creative use of them. . . . History teaches that control of technology is at best a rear-guard action, achievable (and then only briefly) at the cost of regulations and secrecy that carry harmful side-effects of their own."

One of those effects was discussed by Edward Teller, who is not noted for radical views of science and its management, in these pages last month (*see "Secrecy: The Road to Nowhere," page 12*): "As long as (the weapons of the future) are secret, they cannot even be discussed, much less limited . . . Science thrives on openness."—*J.M.*

LETTERS

Scientific Method and Creationism

Regarding "Creationism in the Classroom" by Robert C. Cowen (*July, p. 8*), scientific creationism does not use or depend upon Biblical reference for its substance. Its tenets are: The universe, solar system, and life were suddenly created; all present living animals and plants have remained fixed since creation (other than extinctions), and genetic variaton has occurred only within narrow limits; the processes of mutation and natural selection are insufficient to have brought about any emergence of present life from simple primordial organisms; humans and apes have separate ancestries; the earth's geologic features appear to have been fashioned largely by catastrophic processes affecting the earth on a global and regional scale; and the inception of the earth and living kinds may have been relatively recent.

Creationists are asking that both evolution and creation be open to scrutiny in the public schools. Allowing one philososphy to continue unchallenged is poor scientific and teaching practice. This is especially true today when so many scientists (noncreationists) are openly questioning components of the "theory" of evolution, as Mr. Cowen admits. After all, if mechanisms of evolution are in doubt, isn't the "theory" suspect too?
Kenneth B. Cumming
El Cajon, Calif.

Dr. Cumming is a research associate in bioscience at the Institute for Creation Research at the Christian Heritage College.—Ed.

Proponents of creationism should be asked if they are willing to see the Bible's creation story thrown into the scientific arena for rational analysis. Will they permit the book of Genesis to be evaluated with the same unfettered standards they would apply to the writings of Newton, Einstein, and Darwin?

It would appear that—leaving evolution completely out of it—this "rational-inquiry" approach opens up theological conflicts outside the province of public-school science teachers. Thus, once divorced from its religious base and subjected to a "probability factor" based on physical evidence alone, "creationist science" is likely to make skeptics of the faithful while driving a wedge of medieval irrationality into the study of science itself.
E. Scott Pattison
Dunedin, Fla.

Noncreationists theorize that simple molecules coalesced into more complex molecules, thence into living cells, eventually evolving into the living beings that exist today. But this is unscientific—it violates the second law of thermodynamics, which states that the natural tendency of matter is to proceed from order to disorder. No matter how much time we allow for evolution, processes that are naturally disordering today could never have been naturally ordering—this is like time running backward. Concurrent with the disordering impact humans have on the environment are countless ordering processes restoring the earth, the programs for which are written by a Being whose intelligence is infinitely beyond our reach.
F. Greg Shinskey
Foxboro, Mass.

Mr. Shinskey is a systems development consultant at The Foxboro Co.—Ed.

Nearly everything from fossils to phylum relationships backs up evolution. Yet special creationists say their proof is in the Bible. I wish they would give me the verses that refute comparative morphology, development of vestigial organs, embryology, and anthropology. Let's look at the facts, not at pre-twentieth-century dogma.
Charles F. Weiss
Silver Spring, Md.

States' Rights and Nuclear Sites

"A Nuclear Power Plant in Whose Back Yard?" (*May/June, p. 64*) by Walter Cooper raises more than a few hackles as I find that both his facts and logic are in error:

☐ The three nuclear plants in Maryland were killed for reasons other than siting.

☐ The concept of "indirect" state control of nuclear plants (by requiring that nonnuclear alternatives be considered part of a permit application) is hardly unique or "indirect." In Chapter 9 of every utility's environmental report is a discussion of alternatives, including no new generating capability, nonnuclear generation alternatives, and alternative sites.

☐ New York requires consideration of two sites for coal-fired plants.

Mr. Cooper apparently feels that the states need more regulatory power to permit their arbitrary denial of this land use, particularly when established health and safety standards and power and environmental criteria are met. Despite Mr. Cooper's obvious familiarity with state initiatives in siting both fossil and nuclear power plants, he ignores regulatory powers concerning water use, discharge permits, and transmission line siting. These powers, traditionally the province of the states, have been exercised in several instances to stop unwanted development of power plants.
Morton I. Goldman
Rockville, Md.

Mr. Goldman is senior vice-president of the Environmental Systems Group of the NUS Corp.—Ed.

Plan for All Alternatives

Robert E. Hall and Robert S. Pindyck (*"Oil Shocks and Western Equilibrium," May/June, page 32*) assume that energy prices will continue their hefty increases. Though that scenario is widely accepted, alternative scenarios should always be considered to prevent the most serious consequence of poor planning—not the shock itself but the shock of being unprepared for the shock. The issue is critical now because planners seem to regard further increases in the price of energy as so certain that alternatives need no longer be considered.
Jeff Stollman
Boulder, Colo.

Less, Not More

Kenneth Boulding in "Cowboy Economics" (*May/June, p. 6*) is convinced that President Reagan wants to eliminate all one-way public transfers and leave the country completely in the hands of private enterprise. But the new administration, with unprecedented public support, wants to cut some of the tentacles choking the free-enterprise system—less regulation, not no regulation. It wants to define a new basis for welfare support, food stamps, grants, federal pensions, and low-interest loans, not eliminate them. Can anyone claim that the federal debt has not become unmanageable? If the federal government keeps mounting ever-increasing deficits, the interest will bankrupt the country.
Norman Kantsky
Littleton, Colo.

What Makes Good Cities?

It is possible to agree with the intent of an argument while questioning the scholarship, historical accuracy, and conclusions drawn therefrom. I.M. Pei, in "Reflections on the Resurrection of Urban Design" (*April, p. 18*), implies that successful civic
Continued on page 87

Kenneth Boulding

Bargaining for What?

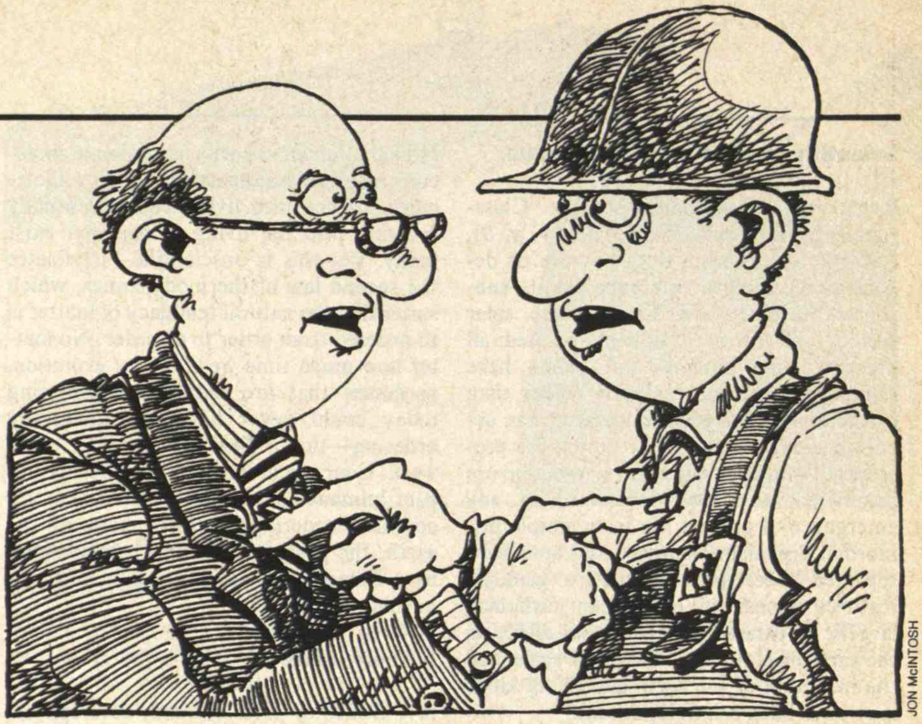
As a sometime student of the labor movement, I have always felt a certain ambivalence about collective bargaining—the old two-handed economist again? On the one hand, I have sympathized with the Galbraith thesis of the necessity for countervailing power and the development of what might be called "labor jurisprudence"—grievance procedures, conciliation and arbitration mechanisms, and protection of the individual worker from arbitrary and inhumane treatment by bosses.

The employer-employee relationship is a very complex and difficult one. Giving employment is very different from buying and selling stocks and bonds or dealing with a product. In the purchase and sale of commodities or securities, what the buyer gives up is pretty much the same as what the seller receives, and what the seller gives up is pretty much the same as what the buyer receives. By contrast, what employers give up are alternative uses of the money paid in wages. This is not at all what employees receive; instead, they gain the real goods and services that can be bought with the wages. Similarly, employees give up alternative uses of their time, but this is not what employers receive. They receive the results of their employees' activities as changes in their asset structure and net worth. The sociological considerations are so overwhelming that they quite overshadow the simple economic exchange.

Unspoken Agreements

Furthermore, the labor bargain contains strong elements of reciprocity ("I'll do something nice for you out of the goodness of my heart and you do something nice for me out of the goodness of yours"). The terms of reciprocity are important—that is, how much each party gets per unit of what each gives. If the goodness of your heart does not lead you to give me very much, the goodness of mine may shrivel a bit. Reciprocity differs from exchange in that it is informal, noncontractual, and difficult to measure.

A labor bargain is similar in some respects to a marriage. The employer pays the employee a wage, not to deliver a well-defined commodity, the quality of which can easily be checked, but to participate in a complex social process of production. This process may also involve a good deal



JON McINTOSH

of judgment on the part of the employee; there must therefore be a certain amount of trust and a fairly complex interpersonal relationship. Similarly, an employee gives up a portion of life in return not only for a wage but also for the conditions of work, personal relations, sense of achievement, and participation in the social process.

It is not surprising, then, that the employer-employee relationship is fraught with difficulty. Often the images that each has of the other do not correspond. I once saw a study of a union-management relationship showing that not only did the people on the union committee have a completely different image of the situation from that of the management representatives, but each management representative had a different image from the other management representatives. When everybody is acting in an imaginary world, it is very easy to develop a dynamic that makes everybody worse off. Bargaining under these circumstances easily becomes pathological, time consuming, and costly.

Retail trade and organized markets for commodities and securities have seen a great diminution in bargaining over the last 300 years. In earlier societies, and still in many societies around the world, haggling and bargaining is an essential element of retail trade, whereas in the world of supermarkets and department stores, it is virtually unknown, though it still survives in real estate. The custom of the fixed price—take it or leave it—which replaced bargaining has been attributed to the moral scruples of the Quakers against lying (which bargaining usually implies), but the history is probably much more complex.

In unorganized labor markets, bargaining is rare, though not unknown, and offers of employment at a publicly announced wage are often as much take-it-or-leave-it as the offer to sell commodities in a supermarket. When markets are active and competition is effective, nonbargaining seems to pay off. In the Second World War, for instance, in a period of very tight labor markets and low unemployment, the wages of unorganized labor increased almost twice as fast as the wages of organized labor, simply because of the delay involved in collective bargaining. In a depression, however, the wages of unorganized labor typically fall much faster than those of organized labor. Nevertheless, the benefits of well-managed collective bargaining are quite real in terms of replacing vague and easily abused reciprocity and informality with respect to contracts, grievance procedures, and industrial jurisprudence.

Who Really Pays?

Now, however, we come to the "other hand"—reciprocity has costs as well as benefits. Formal contracts can lead to hostile, negative attitudes in the workplace, with a resulting loss of quality in work and product. Collective bargaining can also lead to monopoly power and restrictions of entry wielded not just by the employer but by the richer and organized workers at the expense of the poorer and unorganized workers. The question is, who really sits on the other side of the bargaining table? Who

Continued on page 20

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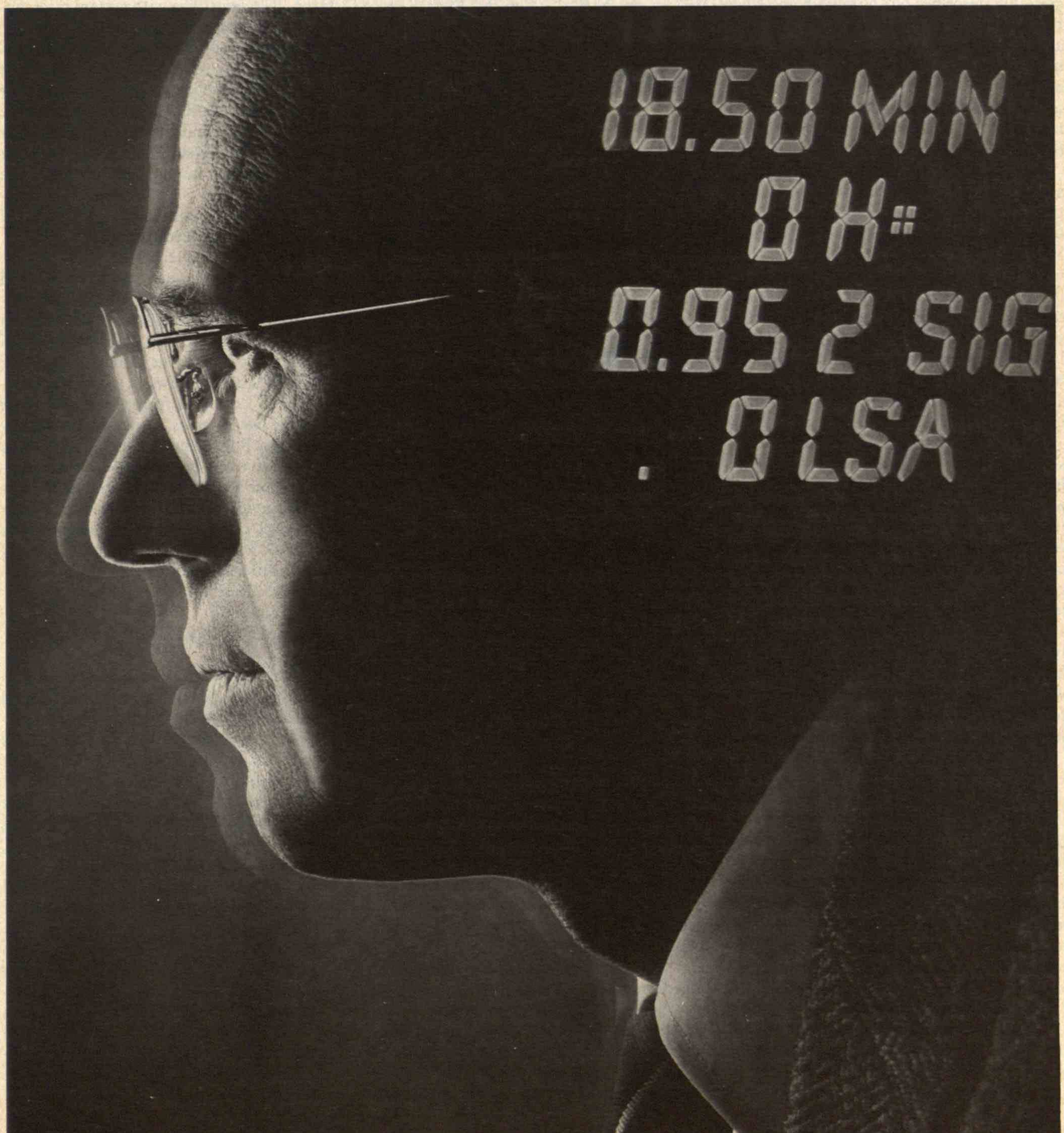


Robert Cowen

Cottage Computing: Glorifying the Trivial?

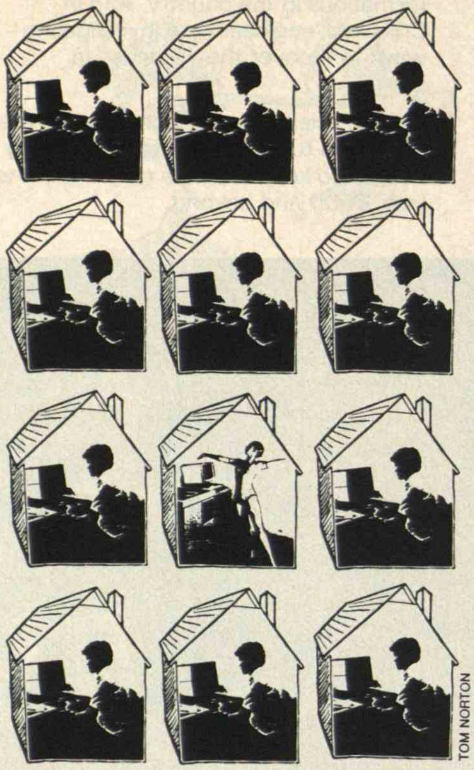
I am writing this column in an "electronic cottage." Alvin Toffler's colorful phrase certainly describes our humble home since the microcomputer moved in six months ago, yet it is hard to feel part of the revolution predicted by Toffler and other prophets of the home computer age. Indeed, the challenge of these marvelous machines may be somewhat different than such imaginative phrase making suggests.

Working at home holds little novelty for a newspaper correspondent who has done it throughout his career from various locations in the United States and abroad. Writing on a computer with a versatile word-processing program that can dump the results over the telephone line to the opposite number in the downtown office is very convenient. But it is not fundamentally different from doing things the old way—banging out the story on a typewriter and dictating it by phone, mailing it in, or handing it to Western Union.

In *The Third Wave*, Mr. Toffler envisions millions of Americans working at home with computers. "What we're talking about is returning production to the home, which is where it was before the Industrial Revolution," he says. Millions of Americans already work at home—almost 2.6 million or 3.2 percent of the 1975 U.S. labor force, to use the latest available census estimate. As in my case, many will likely find the computer a useful tool. It is much less clear that millions of new home workers will join them, except for a relative few such as the physically handicapped, for whom computers have special advantages.

Professor John Owen of Wayne State University believes that while some office work may be shifted to the home, it will be difficult if not impossible to move much production out of the factory. Kenneth G. Bosomworth of International Resource and Development, an office-automation consulting firm, says, "There are not that many types of white-collar or blue-collar jobs that can be done on a lonely basis." He concludes that "only 1 or 2 percent of the work force can [work] in this way."

The *New York Times* has also reported that Jack M. Niles, director of interdisciplinary programs at the University of Southern California, thinks 15 percent of the urban work force, primarily people



TOM NORTON

engaged in information handling, may work at home by 1990. While that would be a significant fraction of that labor sector, it still wouldn't be the "electronic cottage" revolution Mr. Toffler describes.

One can gain a greater sense of revolutionary possibilities by logging on to one of the databanks—"information utilities," to use the trendy term—over the phone line. These are not the databanks that business and professional people have been using for some time, but relatively new services provided for the home computer user. Two of the most prominent are offered by CompuServe, a unit of H&R Block, and The Source, an enterprise in which *Reader's Digest* has invested. The databanks offer electronic editions of some newspapers and wire services such as the Associated Press, electronic mail among subscribers, games, the use of large "mainframe" computers, government publications, magazines, and the like. Although these options can be fascinating and useful, whatever revolution they may portend is ill-defined and its timing uncertain.

The Computer of Babel

From the viewpoint of ordinary home users—as distinct from computer buffs and inquisitive science writers—these databanks offer little to justify their cost, which runs to $5 an hour and up, let alone the price of equipment to tap them or the effort to master their use. They are cranky and idiosyncratic. Not only are the protocols to gain access to their files different for different databanks, they are even different within one utility.

Users have to remember, or hunt up, dozens of commands with different syntaxes. They must live with system interruptions, computer hangups, and, expectedly, telephone cutoffs. However, these management problems reflect the rapid growth of these services, which sprang into being over the past two years, and they are solvable. What is more fundamental is that neither the users nor the suppliers yet know what services should be supplied. Indeed, the *Washington Post* is quite frank about calling its electronic edition experimental and asking for reader feedback.

Consider the electronic newspapers. What you get on your screen is a serial readout of selected stories that can be chosen from a menu of contents and stored on your own magnetic disk or printed out on your home printer. This is fine for someone like me for whom news is a commodity—any quote I can crib from the *Washington Post* or *Los Angeles Times* brightens my own copy. But for most home users, this is an expensive way to read out-of-town newspapers you are not that interested in anyway. The video display can also strain your eyes. One can say the same things about electronic mail that reaches only a limited circle of people, electronic banking, and so forth.

The Hard Side of Software

What is needed are new concepts of services that will enable us to do useful and rewarding things that we couldn't do before. Merely to use computers to do things we already do with less expense and effort would be foolish. Yet this is about all that has been offered so far. Home computers have been touted as helpers for preparing income tax returns, filing recipes, teaching, or gaining access to databanks. But relatively few people's taxes are complicated enough to justify computer handling, and it would be tedious to type recipes into a computer when they are more easily stored and retrieved from cookbooks, card files, and envelopes of clippings. Friends sometimes ask if I have put the family budget on the computer, but I haven't because I can easily keep track of it with a pocket calculator. Why glorify the trivial? There will be

Continued on page 20

Corn Genes and Big Dollars

by Norman Myers

CORN growers in the United States, as in several other leading corn-growing countries, have recently been excited about the discovery of a wild plant in a remote montane forest of Jalisco State in southwestern Mexico. Called *Zea diploperennis*, this plant is the most primitive relative of modern corn. Although only a few thousand stalks of the weedlike plant survive, these could be worth many millions of dollars.

Several sleuths tracked the plant down, notably Ing. Rafael Guzman of the University of Guadalajara in Mexico, with colleagues Professor Hugh H. Iltis and Dr. John Doebley of the University of Wisconsin and Dr. B. Pazy of the Hebrew University of Jerusalem. The wild corn possesses rhizomes that make it a perennial, unlike conventional types of corn, which are annuals. Although the new variety is only remotely related to modern corn, it is a

DAN COLLINS

diploid with 20 chromosomes, as are annual forms, and thus can be crossbred with commercial varieties. This breeding potential points to several breakthroughs for the world corn-growing industry.

During the past several decades, plant geneticists and agronomists have enabled U.S. farmers to produce over three times more corn—100 bushels—per acre. Although a good part of this increased productivity can be attributed to massive amounts of fertilizer, insecticides, and other inputs, American agronomists reckon that 40 to 60 percent can be attributed to the continuous redesign of the corn's genetic constitution.

Genetic engineering has elevated corn to the ranks of the most efficient plants on earth for converting solar energy into food. At roughly 400 million metric tons a year, corn—along with wheat and rice—is one of the "big three" cereal grains, each accounting for around one-quarter of world grain production. Way out in front as the major corn producer is the United States, which grows almost half the world's crop. U.S. cornlands include some 70 million acres—an area the size of Arizona—making corn America's largest crop and representing almost one-fifth of all U.S. cultivation. More than 1 million farmers grow 7 billion bushels a year valued at well over $20 billion.

Searching for the Cream of Wheat

by Robert Cooke

WHEAT, the source of our daily bread, originated long ago as wild grasses, probably in the Middle East. The seeds have been selected, nurtured, planted, and replanted since prehistoric times, gradually transforming these ancient grasses into the wheat varieties that feed the world.

That gradual improvement process is accelerating. Geneticists, who in the past half-century have produced an astounding agricultural revolution with corn, sorghum, and other crops, are focusing their efforts more strongly on wheat. And though wheat is more difficult to manipulate, dramatic strides are now being made.

Some of the most productive work—still based on conventional breeding techniques—is being done in Mexico, at the International Maize and Wheat Improvement Center, where development efforts proceed on a massive scale. Indeed, some 250 new wheat varieties—bred for productivity, disease resistance, hardiness, and the ability to stand up to wind—are sent abroad yearly for testing in international nurseries. Many have become the parent varieties for breeding programs in other tropical nations.

In the United States, where the world's most productive farmers grow much of the grain that feeds the world, the pace of change in wheat has been less revolutionary. The vigorous new Mexican varieties—fit for the Green Revolution—were developed primarily for tropical and subtropical regions, and they haven't matched well with U.S. growing conditions, except in some desert areas of Southern California. As a result, gains in productivity haven't been as dramatic.

But if work on new wheat varieties—and especially the pioneering work on new hybrid wheats—proves successful, significant improvements in yield from domestic crops may be just around the corner. For example, at the Cargill research farm in Fort Collins, Colo., near the front range of the Rocky Mountains, the breeding of true hybrid wheat is a full-time effort.

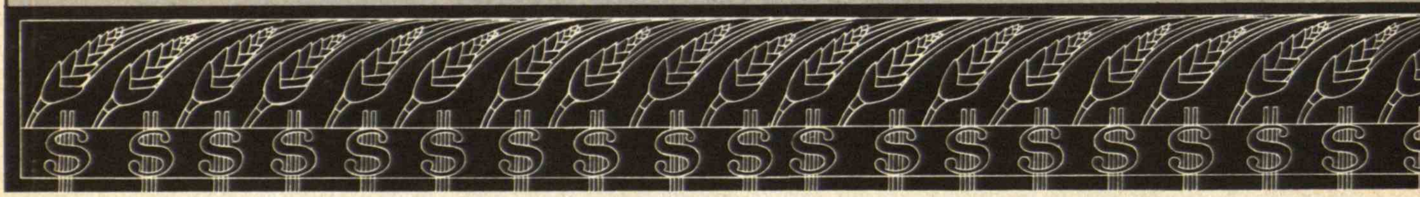
The breeding process can be painfully slow. Not only are crosses difficult to make, but many of the new crossbred plants, even some that seem most promising, are discarded one-by-one because of some weakness. Thus, seeds from only a few plants out of thousands make it from one selection to the next.

What Cargill researchers seek most of all is to harness what's known as "hybrid vigor." The signs are encouraging: they expect within the next few years to offer American farmers new hybrids capable of outproducing present varieties by at least 20 percent.

That figure—20 percent—might be called the "magic number" for commercial production of wheat seed. Anything less than a 20 percent improvement in yield, the researchers warn, isn't enough to induce farmers to buy expensive new seed.

In the United States, winter wheat production comes close to 1.75 billion bushels. Boosting that by 20 percent would mean an extra 350 million bushels, and similar gains could be expected in Canada, Australia, and Argentina if hybrids are adopted.

Such an achievement is an elusive goal. Unlike corn, wheat production hasn't really benefited yet from the introduction of true hybrids. Extensive crossbreeding has been



But without regular infusions of fresh germ plasm, or genes, America's corn productivity cannot be maintained at present lofty levels, let alone pushed still higher. Like all modern crops, corn needs regular boosts of new genetic material to keep it flourishing, so there is a constant emphasis on "topping up" its genetic constitution with additional genes.

The United States is highly dependent on foreign germ plasm for its corn crop. Corn originated in Central America, and it is primarily from this region, together with neighboring tropical areas, that the most diversified sources of corn germ plasm are sought. Without these gene supplies from beyond its southern border, the U.S. corn crop would have a very restricted genetic base. More than 70 percent of the U.S. crop derives from only six parent lines, meaning that billions of corn plants are almost identical. It also means that whatever gene combination makes one plant susceptible to disease or environmental stress may make all its genetic siblings susceptible. To cite Professor J. Artie Browning of Iowa State University, the country's cornlands are "like a tinder-dry prairie waiting for a spark to ignite it."

For example, in 1970 a new leaf fungus blighted cornfields from the Great Lakes to the Gulf of Mexico, and America's great corn belt almost came unbuckled. Roughly 15 percent of the crop was destroyed, and in some parts of the South more than half the crop was lost. Fortunately, thanks to the development of a blight-resistant hybrid seed, the situation was saved by the following year.

Despite this near-disastrous experience, America's corn crop is hardly less vulnerable today. Professor Jack Harlan, a noted agricultural expert at the University of Illinois, summarized genetic stocks for all crops around the world: "Seed collections stand between us and catastrophic starvation on a scale we cannot imagine. In a very real sense, the future of the human race rides on these materials. Yet most of our so-called world collections are sadly deficient in wild races. As we obtain more and more useful results from incorporating wild genetic resources, the principal bottleneck lies in the paucity of wild germ plasm in our collections."

The perennial corn recently discovered in Mexico survives in a handful of tiny populations covering less than ten acres, and these last habitats are threatened by settlement schemes, squatter cultivators, and timber-cutting enterprises. The value of this corn is hotly debated. If it could be crossbred with conventional corn, making a perennial hybrid, the fact that farmers could grow their corn without the annual

Continued on page 64

done, but in almost all instances—except for a few recent attempts—new introductions have been what are called "new varieties," not true hybrids with hybrid vigor.

Plant breeders have long known that the first generation of offspring from crossed varieties tends to be more vigorous than offspring from more inbred varieties. This vigor can show up as better disease resistance, climatic tolerance, shorter growing season, higher yield, or even better milling and baking qualities. The goal, of course, is to transfer as many of these desired characteristics as possible into a single type of commercial wheat. And to get true hybrid vigor, the breeder must be able to produce seeds that are first-generation offspring, the reliable product from the crossing of desirable parent plants. Thus, every year the seed grower must produce a new set of first-generation seeds for sale to farmers.

Sex in Cereals

In corn production this was achieved early and relatively easily. Fortunately for breeders, corn bears its sex organs on different parts of the plant. The male pollen-producing part is the tassel, which grows at the top of the plant's main stem. The female part is the ear of corn itself. Pollen normally sprinkles down onto the "corn silk" to fertilize the pistils, the female parts.

Breeders plant the types of corn they want to cross in adjacent rows and then "detassel" every other row. As a result, every other row has plants bearing female organs only, so they're unable to fertilize themselves. These plants are fertilized by pollen falling from tassels on the adjacent rows of corn plants. Thus, large amounts of hybrid seed can be produced by this uncomplicated step.

This technique—even though done by hand labor—was so successful that enough hybrid corn was produced to seed the entire corn acreage of the United States within 20 years after first being introduced in the 1930s. However, in the early 1950s an even better approach to the production of hybrid corn was developed. This involved production of genetically "male-sterile" corn plants in which the female parts are fully functional but the pollen is sterile.

It was also found that by using the right genetic combinations, fertility could be restored to the vigorous first-generation corn plants so they produce seed. This eliminated the need to detassel thousands of corn plants in a breeding plot.

But the story is very different for wheat. Unlike corn, wheat plants bear their sex organs nestled close together in the little spikelets, or flowers. This means that wheat is self-fertile; pollen is normally deposited onto the pistil well before the flower opens. No simple large-scale method such as detasseling can be used to produce hybrid seed.

Designer Genes

However, breeders have been able to make small-scale crosses by carefully opening the individual spikelets before the pollen is ripe and removing the pollen-producing anthers. This process is called emasculation. The emasculated wheat heads are then fertilized (crossbred) by hand-sprinkling in pollen from a different plant.

Unfortunately, this process is very slow and incapable of producing large amounts of hybrid seed. Some improved wheat varieties—including those important in the Green Revolution—have been produced

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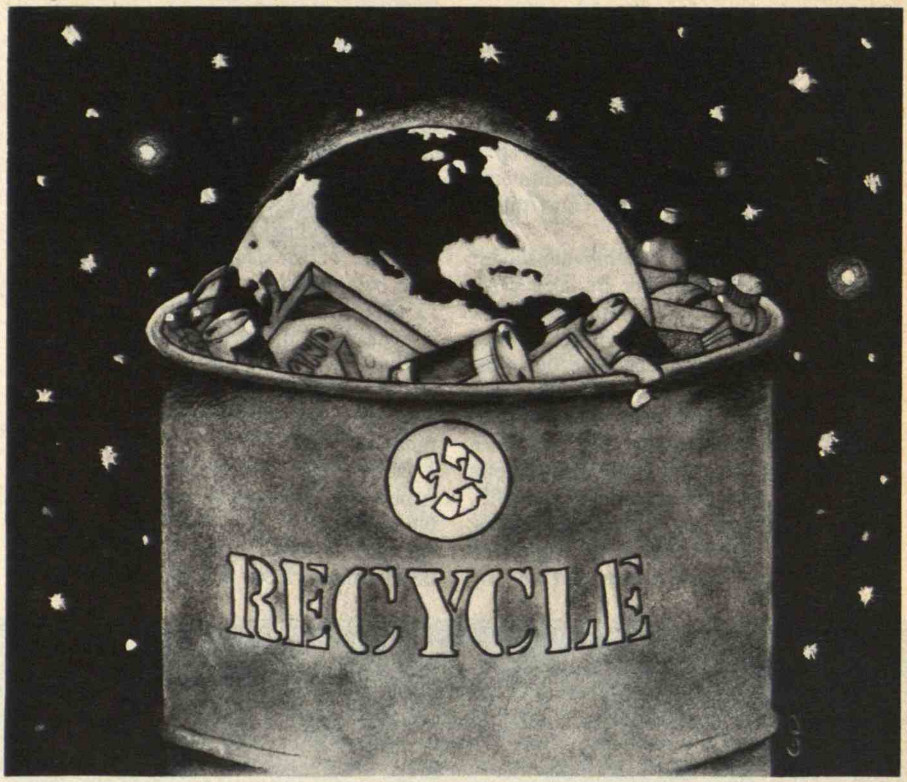
Building in Environmental Costs

by David Gordon Wilson



GARY DAVIS

"WHERE there's muck there's brass" is an oft-quoted Yorkshire expression supporting the popular belief that environmental pollution ("muck") is a necessary accompaniment to economic betterment ("brass," or money). I grew up in the English Midlands just east of where much of the early Industrial Revolution took place. We would travel west to Wales through the Black Country, an area that seemed almost devoid of trees or other vegetation—unending heaps of mine wastes, separated only by ancient factories and foundries with belching smokestacks, and rows of houses thrown up to accommodate urban immigrants forced out of their rural villages by inhumane legislation.

Despite this horrible spoliation of natural beauty wrought by industry in many parts of Britain, the environmental disasters we have brought about more recently seem likely to rank as far more serious. Atomic testing in Nevada and the Pacific, contamination of animal feed with polybrominated biphenyls (PBBs) in Michigan, and the dumping of toxic wastes in Love Canal are well-known examples in the United States of what ultimately will be many instances where human actions, ranging from the well-intentioned but misguided to the criminally callous, have resulted in health and environmental effects tragic to the point of disaster.

The situation in the Third World is, ironically, especially hazardous because of the partial success of environmental movements in the industrial countries. Restrictions or bans on many substances have led producers in developed countries to look for markets elsewhere—mainly in nonindustrialized developing countries with few restrictions. A prominent example is tobacco, a major factor in cancer, heart disease, and other serious ailments. According to government estimates, the use of tobacco leads to a quarter-million premature deaths yearly in the United States alone. Yet the U.S. tobacco industry employs slick advertising abroad to promote smoking as one of the keys to the American way of life, and has greatly increased sales (aided to some extent by U.S. government programs) in the last decade.

Likewise, other products, from pesticides to dielectrics, found hazardous in the U.S. (and in some cases banned from sale) are sold widely in developing countries without strong environmental-protection legislation or enforcement. There are no reasons why substances considered hazardous in the U.S. should not be equally hazardous elsewhere. Strict environmental laws are urgently needed everywhere to prevent massive future disasters.

Confusion over Legislation

In some ways, substances so hazardous that a total ban is required are the easy cases. Of more interest are those pollutants that, though unpleasant or unhealthy, are an inevitable consequence of desired activities and can be tolerated up to certain levels. I believe much confusion over environmental legislation results from not recognizing the role of "externalities" in the modern world, and the legislative steps that can be taken to control and channel them.

Externalities are unintended costs imposed on groups or individuals as a result of actions taken by others. Someone opening a fast-food restaurant may make a substantial profit from the enterprise, and customers may appreciate the low prices and quick service. However, neighboring businesses may continually have to clean up litter thrown away by the fast-food customers, and heavy traffic may hinder their own customers. These neighboring businesses pay the external costs of the fast-food restaurant.

In simple societies, the scope for imposing externalities is very limited. People travel by foot and cultivate fields by hand. Any damage to someone else occurs, and is usually handled, on a personal level. Technology has greatly extended our interactions and the possibilities of external damages have become vast and complex.

We can travel long distances at high speeds to places with fragile ecologies, causing irritation and danger to others, threatening the existence of whole species of living things, and using up the earth's limited resources at an accelerating pace. For example, as we consume our petroleum reserve, that oil is not available to our descendants. They will face additional costs, and—because they were not parties to our decisions to use the petroleum—those costs are truly external. Also, our methods of production have become so efficient that when one of our gadgets malfunctions, it is often cheaper simply to throw away the broken component, or even

the complete unit, and buy a new one, rather than attempt to repair it. The discards become external costs borne at least partly by others.

Some Modest Proposals

Economists generally agree that externalities should be "internalized" so far as politically practicable. I would like to suggest ways of legislating this internalization, focusing on solid wastes.

Disposal Tax. Final disposal of solid waste is generally not the responsibility of the person discarding the waste. Normally it is deposited in an appropriate receptacle and a service provided by the local government removes the refuse for treatment. A solid-waste-disposal tax has been proposed as a means of including the cost of hygienic disposal in the cost of an item. The average cost of pickup and disposal for the country could be estimated: in the United States it is currently three to four cents per kilogram. This per-kilogram amount would then be imposed as a national tax on material or individual items destined for pickup and disposal by local-government services. Principal candidates are glass, plastic, steel, and aluminum used in food and drink containers; newspapers and magazines; and paper, cardboard, and plastics used for containers, wrapping, and shipping. The total money collected would be distributed among municipalities in proportion to the solid wastes collected by each.

Litter Tax. Some people do not dispose of their solid waste in appropriate receptacles, but instead drop it wherever they happen to be. Other people, usually municipal workers, then pick up the litter. Exact internalization of the costs of litter pickup and disposal—by fining every person who litters—would be fair. However, this would require an unacceptably large police force and judicial system, and most communities instead choose to make exemplary fines on the few litterers caught and convicted.

A closer degree of internalization than provided by charging the costs of litter pickup to the total community would be achieved by putting the cost on the chief offenders via the marketplace. Twice a year a careful sampling of the litter picked up in representative areas should be made. The litter could be divided into soft-drink containers, liquor containers, cigarette litter, newspapers and magazines, and food wrappings. The number of pieces, weight, and

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A Wall Street for Pollution?

by Steven J. Marcus

James Bond, high-living Agent 007 of the British Secret Service, would probably refuse to estimate the "value of a life." Yet he is endowed by author Ian Fleming with a "license to kill"—a regrettable but presumably inevitable requirement (at least in novels) for international espionage.

Among environmental analysts and regulators, and even among industrial polluters, a similar strategy is being developed: it makes little sense to put a dollar value on intangibles such as clean air or clean water, but it might make a good deal of sense to issue "licenses to pollute"—permits for pollutant discharges that have been offset by reductions nearby—and to let the marketplace set dollar values on these permits. This will allegedly help to establish practical economic incentives in place of centralized, often unwieldy, governmental regulation.

"Controlled trading of pollutant permits," according to Dr. Clifford S. Russell (an economist with Resources for the Future), "represents a step toward flexibility and economic efficiency." Describing the various properties—far from exhaustive at this early stage—of permit markets in a recent article in *Environmental Science and Technology*, he asserts that such trading not only "holds real promise of reducing some of the most disturbing deficiencies of our existing system of pollution management" but actually represents a "tendency toward least-cost distribution of the burden."

The U.S. Environmental Protection Agency (EPA) actually began two such economic-incentive programs during the Carter administration: the "bubble concept" and the "offset policy." By treating a multisource industrial complex as a single source of an air pollutant (as if the entire plant were under a "bubble"), the company may then abate its overall emission of that pollutant in the most cost-effective manner, successively employing the least costly techniques until the standard is met. This would eliminate the need for source-by-source optimization within the plant or, even better, the need to implement government-specified pollution controls for each source. "We want the skill and creativity of business's engineers turned to the environment's business," declared then-EPA Administrator Douglas M. Costle in 1979 when the "bubble concept" was announced.

The bubble is not really a "market," since all trade-offs take place on the premises of a single plant, but it is nevertheless an important precursor. At this writing, 70 bubbles are being developed and 30 have been submitted for approval. The strategy is particularly favored for its "bottom-line" appeal; DuPont's Chairman Irving S. Shapiro contends that "a properly conceived bubble approach would permit us to provide the same environmental benefits at 40 percent of the cost of source-by-source controls."

While the bubble concept enables a single company to begin "internalizing its externalities," the offset policy can bring several entities under an expanded bubble and thus create a market in pollution rights; one company's abatement can be a tradable commodity for another (new or expanding) company in the same region. In effect, an increase in emission from one source is offset by a decrease in another under a straightforward business transaction. Thus, General Motors has struck just such a deal to construct a facility in Oklahoma City, and Volkswagen of America used the offset policy to advantage for locating a plant in New Stanton, Pa.

The prospects of "banking" pollutant-abatement credits, third-party "brokering" to effect offset agreements, and a full range of economic institutions that would comprise a virtual Wall Street of pollution are clearly suggested. And in fact the *Wall Street Journal* recently cited two such examples: a professional pollutant broker in Richmond, Calif., and a Milwaukee bank, the First Wisconsin Corp., that performs pollution-credit accounting for its clients.

The field is in its infancy, and much remains to be designed and tested if the partial failures of traditional markets

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Polywater Doodle All the Day

Polywater
Felix Franks
Cambridge: M.I.T. Press, 1981, 208 pp. $15

Reviewed by Fred Wilson

I first heard about polywater in the fall of 1969, shortly after arriving at the Rochester Institute of Technology. Some of our chemistry faculty were agog with the news of an anomalous form of water, reported to have characteristics of a polymer (thus the name), a viscosity 15 times that of normal water, a freezing temperature of -30° C, and a boiling point of 250° C.

I was serving on an Institute Environmental Committee with a "pro-poly" chemist and the director of our Distillation Laboratory. One entire meeting of the committee dissolved into a heated exchange between the two. The chemist was excited because if the water had anomalous properties, it presented a fantastic opportunity for research. The director of the Distillation Laboratory, a grand gentleman with years of painstaking research behind him, dismissed the entire concept with a wave of the hand and snorted that polywater was so much "contamination of fatty acids."

I followed up on this exchange by reading all the articles on the subject I could lay my hands on. The controversy was hot and opinions were strongly polarized. Eventually I sided with the "antis." Then, in the 1970s, when polywater was finally dismissed categorically as an artifact—as merely contaminated water—I was proud of my rational behavior, clear thinking, and scientific objectivity.

Casting the First Stone

But I was as guilty of making a rash judgment as those who reported polywater's discovery, as Felix Franks clearly reminded me in his book. I did not have an adequate scientific base on which to make my decision. If the researchers reporting polywater's properties rushed to publication (and Franks makes a good case that they did, sometimes with the support of editors of usually staid and conservative journals), then I was too quick to make a decision based on convention rather than on objective analysis spiced with a healthy skepticism.

Was polywater a humongous hoax or a freak in scientific research that is highly unlikely to recur? The answer lies somewhere in between. The common view is that science proceeds inexorably and without false starts. Another myth is that of the lone experimenter, struggling away in his or her ill-equipped laboratory, making the major breakthrough—quite by accident (à la Goodyear). Alternatively, the advance may come by dint of total commitment against overwhelming odds and the accepted views of established science (à la Pasteur).

An equally prevalent misconception holds that science can and should solve any major world problem. If Mt. St. Helens belches smoke and quivers, it is up to science to turn it off. If the mountain erupts, it is the fault of science for not having done something.

Views such as these can put enormous pressure on scientists, especially if they are held by persons in high places. In *Polywater*, Felix Franks gives a look, from within science, at factors that contributed to such views in society, a highly personal account by an eminent scientist. It is no surprise that Franks mentions James Watson's *Double Helix*, for his own account is certainly Watsonish. In *The Eighth Day of Creation* Horace Treeland Judson gives an account of Watson's book. "The manner is authoritarian. There is urgency, even salt, but reflection is not stayed for, argument is not brooked. Thus the intellectual texture of science in process is, I think, stifled, which is a loss of what ought to be a first, if most intangible, concern of great teaching."

One gets much the same feeling from reading Frank's book: "The editors of *Nature* and *Physical Review Letters* saw fit to publish such metaphysics. . . . There is evidence here of schizoid behavior. . . . It has also led to a generation of scientists . . . who, on occasion, substitute computer power for insight and originality."

To those working in science, the failure of the concept of polywater and its ultimate identification as an artifact is not uncommon. Why then was there such an overwhelming number of able people involved in polywater research when an artifact was suspected from the very first?

Dressing the Emperor

The announcement by a highly respected Soviet scientist from a well-known research center that water, so common and basic to life, had anomalous properties was bound to stir interest, curiosity, and skepticism. But this is hardly an adequate rationalization for the lack of skeptical review by those working on it and reviewing the work for publication. The basic problem was the almost immediate resistance to the idea (again without critical testing) that led to a growing polarization of opinion concerning polywater. Those who believed they had found the anomalous properties were attacked. Defending themselves, they took up positions from which they could not back down.

Polarization leads to pressures to perform uncritical experiments to justify these positions. Uncritical research leads to self-deception—a sort of hedonoptica, seeing only what is pleasing to one's eyes. Franks gives a number of examples to support this view.

Perhaps Frank's weakest argument is his analysis of the role of the scientific elite. He says that "the members of the elite are far from infallible, but they are conservative, and in science conservatism pays off more often than not."

The word *conservative* has little meaning here. What should be said is that the scientific elite holds steadfastly to the scientific values that have been carefully constructed over centuries. The values of science include freedom of inquiry, speech and thought, communication, and tolerance, which society protects for all its members. As Jacob Bronowski explained in *Science and Human Values*, when any of these values are violated, science suffers. □

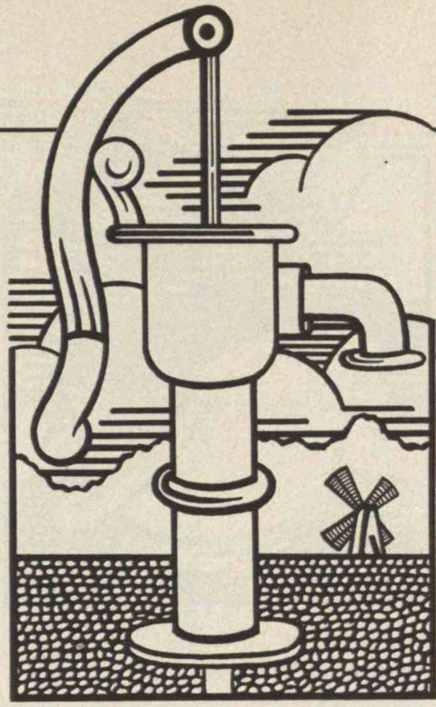
Fred Wilson is a professor in the Science, Technology and Society Program at the Rochester Institute of Technology.

ILLUSTRATIONS: LUCY DILLON

Cutting Technology Down to Size

An Assessment of Technology for Local Development
U.S. Congress, Office of Technology Assessment, 1981

Reviewed by Judith Wagner



Because technology pervades our lives through language, conceptual forms, communications, health care, transportation, and many other daily encounters, it has become inextricably woven into the fabric of our society. Technology is expected to produce solutions to all major problems, even those generated by other technologies. It is traditionally considered the mill wheel of the entire economy, a vital organ in the national economic body.

But since the 1950s, when some noted scientists began actively opposing the stockpiling of nuclear weapons, another view of technology has been advancing. The superiority of technology in its common large-scale, mechanized, and energy-consuming manifestations has been challenged, particularly by environmentalists, who argue that much of today's technology is doing irreparable damage to natural systems. The energy crisis provided new impetus for these debates: over the past ten years the arguments for controlling technologies and reshaping the modes, appetites, and even the purposes of technologies have sharpened. Inherent in these arguments are many assumptions about the need for smaller-scale life-support systems, more direct control of technology by people for their immediate needs, decentralization of basic economic and service systems, and a reordering of priorities for the entire society. Throw in the foreign-policy issues related to energy, and the discussion becomes even more complex.

Less Is More

In the early 1970s, E.F. Schumacher, a maverick British economist, proposed the value of what he first called "intermediate" and later "appropriate technology." In *Small Is Beautiful* he cites appropriate technology as a guiding principle for the solution of the economic problems of poor countries. The concept is attractive, for it suggests ways to improve local economies through a compromise between outmoded indigenous practices and sudden full-scale conversion to a capital-intensive, industrial economy. The concept offers respect for local societies along with strategies for improving basic economic conditions. However, Schumacher's followers quickly transferred these ideas to conditions at home and began asking whether the idea of tailoring technology to each situation could help counteract the disturbing trends of more industrialized countries.

It is this broader interpretation of suitable technology and a more literal use of the word "appropriate" that hold great potential for even highly technical economies. The question becomes "What is appropriate to the task at hand?" The answer is to design systems that meet specific needs without relying on large-scale, centralized systems (such as electrical generating facilities) that, while they might eventually do the job, often waste considerable resources or produce many undesirable side effects. We should stop, as Amory Lovins has put it, cutting our butter with a chain saw.

The concept of appropriate technology has become so familiar that the congressional Office of Technology Assessment recently published a report entitled *An Assessment of Technology for Local Development*. Appropriate technology is defined as that which "involves an attempt to tailor the scale and complexity of a technology to the job that needs to be done on the basis of human values as well as purely economic values; it tries to be sensitive to the needs, desires, and resources of the people who will use the technology." Such technologies, the report explains, ideally emphasize "resource efficiency, environmental soundness, community control, and labor rather than capital intensiveness." The report goes into considerable detail about more ambitious goals for appropriate technology such as answering the complex problems of economic growth, promoting national and domestic equity, and balancing government regulation and citizen participation. It also provides case studies of "promising new technologies . . . that may provide an alternative and possibly more effective approach to community regional development."

More Than Nuts and Bolts

The report offers a very satisfying summary and sample of the more interesting attempts to design alternative methods for fulfilling many community needs. Even for those familiar with standard designs for things such as superinsulated structures, bio-gas digestor sytems, or small-scale hydroelectric systems, this collection offers enough statistical tidbits, sketches and photographs, and technical information on performance to be a valuable resource. Together the case studies (necessarily a bit superficial individually) offer a useful look at the variety of problems—both technical and otherwise—that people confront in implementing alternative systems.

Appropriately, the report also spends considerable time on the social and community influences on each project. As many advocates of appropriate technology have pointed out, the choices are not only among specific technologies but also (and possibly more importantly) among social and political structures.

However, several features of the study are puzzling and, ultimately, disappointing. The introduction suggests that the report will critique each experiment on the basis of a rather elaborate set of goals for solving social, economic, and political problems. But a number of the projects, while different from conventional systems, do not offer any demonstrated advantage, particularly in terms of political and social criteria.

The report's conclusions and recommendations seem to stop short of promising significant changes in technological applications. One of the most frequent recommendations is that there is no need for new federal programs or agencies to support appropriate technology, yet this need is obvious to anyone who has had experience with existing programs—such as the National Center for Appropriate Technology and the Department of Agriculture's Cooperative Extension Service. These programs

are certainly in need of an overhaul or replacement if appropriate technologies are to significantly affect local communities. Short-lived projects and badly managed demonstration programs do not explore the full potential of the technologies being tested.

In its announcement of this report the Office of Technology Assessment states that if widely duplicated, projects such as those described could "play a significant role in meeting pressing national needs." However, the question remains whether such projects will simply become "accepted" technology or whether they will be applied to promote some of the fundamental societal changes necessary for local control of human development. ☐

Judith Wagner, a graduate of M.I.T.'s Urban Studies Program, is former codirector of Boston Urban Gardeners, Inc.

A Shaky Crossing

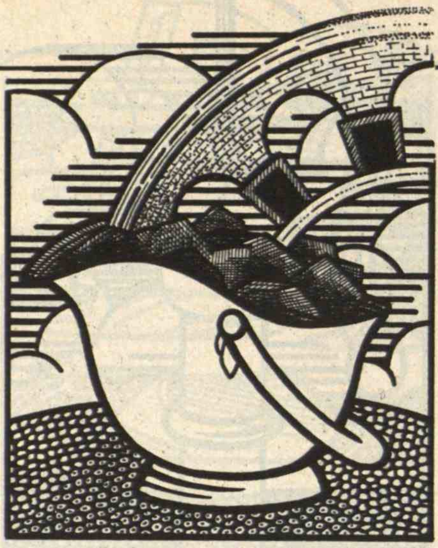
Coal: Bridge to the Future
Report of the World Coal Study
Cambridge, Ma.: Ballinger, 1980, 247 pp.

Reviewed by William Lasser

This report of the World Coal Study (WOCOL), a multinational group of coal experts from 16 countries, takes a distinctively international approach to the energy crisis, stressing the need for a worldwide solution to what is clearly a worldwide problem. Still, it is a decidedly American book in its unbounded hope for the future.

While the members of WOCOL admit that the world has a potentially dismal short-range future because of energy problems (especially oil shortages), they are firm in the belief that eventually everything will work itself out. This is called "cautious optimism."

What is needed, the authors argue, is a bridge, an energy source that will ease the transition over the next two decades from oil dependence to whatever will be the energy source of the future. Coal, they maintain, can be that bridge: it is "versatile in application, easily transported and stored, and reasonably priced," and coal technology is "mature and generally available." That ugly black substance that once filled the air of London with "beloved smoke" can now be burned in conformity with "strict environmental standards . . . at a cost competitive with other fuels."



Shortsighted Solutions

The authors argue that a massive short-term switch from oil to coal is both necessary and feasible, but there are two problems with this proposal. First, the study acknowledges that the public and private sectors of 50 or more countries would have to "act cooperatively and promptly" if coal is to provide the bulk of our increased needs over the next two decades. The current state of world affairs lends no support to the argument that such cooperation is possible, much less likely. The oil crises of the 1970s showed that even long-standing friends will go their own ways when their energy lifelines are threatened.

Second and more important, the authors make no attempt to describe the long-range future or to forecast what energy sources will power us through the twenty-first century. We are told that nuclear energy will play a larger role when (not if) "present uncertainties are resolved." We are also told that after the year 2000 "renewable energy systems should be coming into use on a significant scale." Still, the study is woefully and willfully short on information in this area.

Its recommendations can be accepted as a blueprint for international action only if we have sufficient reason to believe that our energy problems are indeed temporary. For coal is only a bridge to the future, not the future itself.

If we accept the WOCOL view of an energy-rich twenty-first century, the proposal to switch to coal makes sense. In the United States alone, for example, we could triple our coal production by the year 2000 and thus let coal provide almost two-fifths of our energy requirements, up from one-fifth in 1977. Such rapid and wide-scale conversion would not come cheaply, however: WOCOL estimates that total capital investment in coal for the 12 members of the Organization for Economic Cooperation and Development participating in the study would be 1 *trillion* dollars. That figure represents about 3 percent of the aggregate capital formation of these countries over the next 20 years.

Also, massive investment in coal will undoubtedly reduce the amount of capital that can be committed to basic energy research and other energy technologies. But if the promised energy future appears at all, it will be the result of determined effort by thousands of scientists and engineers and of billions of dollars of investment capital, largely from the public sector. We may not be able to afford both the WOCOL plan and research and development in other areas of energy technology.

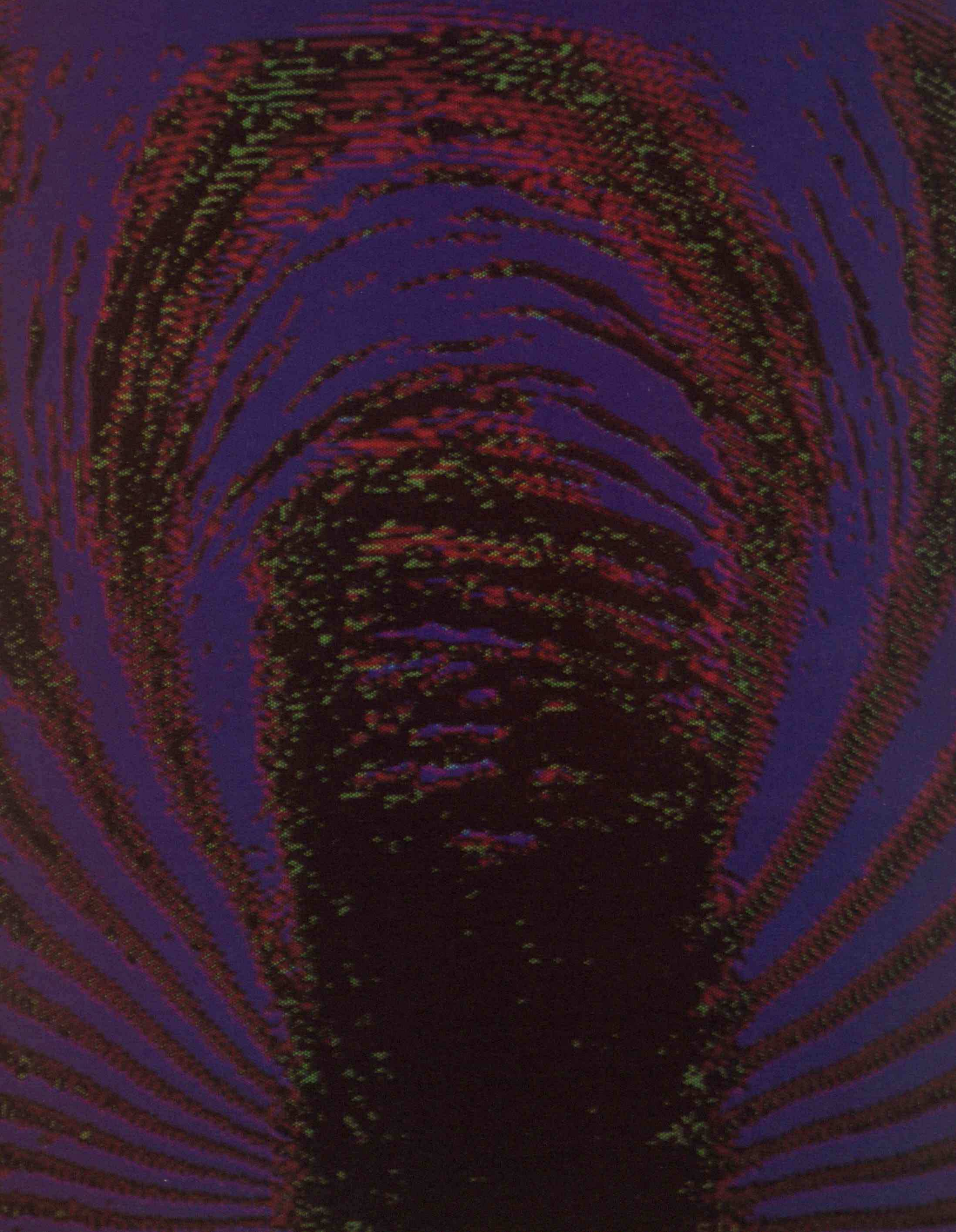
The All-American Pitfall

The fundamental difficulty underlying the WOCOL analysis is a cultural one, however. WOCOL's American approach to problem solving—jerry-rig and hope for a technological breakthrough—has worked in the past because we have always had a virtually limitless reserve of natural and human resources. Neither the authors nor the American people are willing to admit that our luck in this area may be running out. There might be a technological breakthrough within two decades, as the authors suggest, and as most Americans would like to think. But that breakthrough—be it in fusion, fission, solar, or some energy source not yet discovered—may be 50 or 100 years away. Can we afford to take the risk that the coal bridge is too short?

The WOCOL proposal is just another short-term fix. A lasting solution to our energy problems may involve a restructuring of our lifestyles and attitudes toward nature. Such a transformation will not occur by accident—it will require money, planning, and imagination. We will need to consider smaller cities, decreased dependence on the automobile, and—above all—increased conservation. Instead of trying to find enough energy to feed our wasteful habits, we need to learn to live within our energy means. Rather than building a bridge to an uncertain future, perhaps we should plan for and create the future itself. ☐

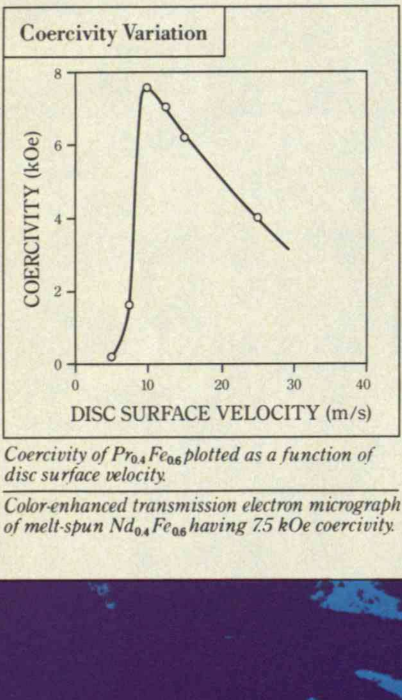
William Lasser is a doctoral candidate in government at Harvard who has worked for the Department of Energy.

The Critical Interval



The Critical Interval

There has long been a need in the industrial world for low-cost, high-performance permanent magnets. Recent discoveries at the General Motors Research Laboratories show promise of meeting this challenge by the application of new preparation techniques to new materials.



Coercivity of $Pr_{0.4}Fe_{0.6}$ plotted as a function of disc surface velocity.

Color-enhanced transmission electron micrograph of melt-spun $Nd_{0.4}Fe_{0.6}$ having 7.5 kOe coercivity.

TWO properties characterize desirable permanent magnets: large coercivity (magnetic hardness or resistance to demagnetization) and high remanence (magnetic strength). Higher-performance magnets are required to reduce further the size and weight of a wide variety of electrical devices, including d.c. motors. Such magnets are available, but the cost of the materials necessary to produce them severely limits their use. The research challenge is to select, synthesize, and magnetically harden economically attractive materials of comparable quality.

Prominent among alternative materials candidates are alloys composed of iron and the abundant light rare earths (lanthanum, cerium, praseodymium, neodymium). Investigations conducted by Drs. John Croat and Jan Herbst at the General Motors Research Laboratories have led to the discovery of a method for magnetically hardening these alloys. By means of a rapid-quench technique, the researchers have achieved coercivities in Pr-Fe and Nd-Fe that are the largest ever reported for any rare earth-iron material.

Drs. Croat and Herbst selected praseodymium-iron and neodymium-iron based upon fundamental considerations which indicate that these alloys would exhibit properties conducive to permanent magnet development. These properties include ferromagnetic alignment of the rare earth and iron magnetic moments, which would foster high remanence, and significant magnetic anisotropy, a crucial prerequisite for large coercivity.

That these materials do not form suitable crystalline compounds, an essential requirement for magnetic hardening by traditional methods, presents a major obstacle. Drs. Croat and Herbst hypothesized that a metastable phase having the necessary properties could be formed by cooling a molten alloy at a sufficiently

rapid rate. They tested this idea by means of the melt-spinning technique, in which a molten alloy is directed onto a cold, rotating disc. The cooling rate, which can be varied by changing the surface velocity of the disc, can easily approach 100,000°C per second. The alloy emerges in the form of a ribbon.

THE researchers found that variations of the cooling rate can dramatically affect the magnetic properties of the solidified alloys. In particular, appreciable coercivity is achieved within a narrow interval of quench rate.

Equally remarkable, synthesis and magnetic hardening, two steps in conventional processing, can be achieved simultaneously.

"X-ray analysis and electron microscopy of the high coercivity alloys reveal an unexpected mixed microstructure," states Dr. Croat. "We observe elongated amorphous regions interspersed with a crystalline rare earth-iron compound."

Understanding the relationship between the coercivity and the microstructure is essential. The two scientists are now studying the extent to which the coercivity is controlled by the shape and composition of the amorphous and crystalline structures.

"The development of significant coercivity is an important and encouraging step," says Dr. Herbst, "but practical application of these materials requires improvement of the remanence. Greater knowledge of the physics governing both properties is the key to meeting the commercial need for permanent magnets."

THE MEN BEHIND THE WORK

Drs. Croat and Herbst are Staff Research Scientists in the Physics Department at the General Motors Research Laboratories.

Dr. Croat (right) received his Ph.D. in metallurgy from Iowa State University. His research interests include the magnetic, magneto-elastic and catalytic properties of pure rare earth metals and their alloys and compounds.

Dr. Herbst (left) received his Ph.D. in physics from Cornell University. In addition to the magnetism of rare earth materials, his research interests include the theory of photo-emission and the physics of fluctuating valence compounds.

Dr. Croat joined General Motors in 1972; Dr. Herbst, in 1977.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The Last Picture Show

A stream of surprises is only just beginning from *Voyager*'s deluge of data.

Voyager 2's August flyby of Saturn will be the last U.S. planetary encounter for five years even if the NASA budget is tripled tomorrow. But a stream of surprises only just beginning is likely to continue from detailed analysis (and some incisive speculation) of the spacecraft's deluge of data. So here's merely a first glance at some of the earliest remarkable visions:

□ The rings of Saturn are now known to number not "just" in the hundreds but in the hundreds of thousands, with some as narrow as a few hundred feet. The gravity of small moonlets within the rings does not channel the trillions of ice chunks that compose the rings into so many narrow traffic lanes, as many scientists had formerly assumed. No such moonlets were detected by the spacecraft, except for the two "shepherds" already discovered by *Voyager 1*, which seem to "keep" the thin outer F Ring in place.

The F Ring shocked astronomers during the flyby of the first *Voyager* because it was noncircular, kinked, and composed of what seemed to be three strands braided together. But pictures made from *Voyager 2* show that the F Ring looks no different near the shepherds than elsewhere, and they also show five strands and no braiding. *Voyager 2* also found that the main rings contained kinks and noncircular features, specifically in a narrow, bright ringlet within the A Ring's Encke Division, and that even the outer edge of the B Ring, the brightest main ring, is slightly elliptical. There are no shepherds near these features.

□ There's more matter associated with the rings than would be expected from data that are converted into photographs: as *Voyager 2* streaked through the ring system's thin, 500-foot-thick outer extension at a relative speed of 8 miles per second, it was bombarded by thousands of dust-sized particles not for 500 feet but for about 1,000 miles. The impacts produced a racket on the spacecraft's radio receivers as each particle struck, vaporized, and ionized.

□ Twelve of Saturn's seventeen known moons were "imaged" in much better detail by the second *Voyager* than by its predecessor. In some cases resolution was so great that features scarcely larger than a city block could be discerned, inviting speculation as to their genesis and significance.

□ Saturn's moon Enceladus shows evidence of recent geologic activity. Enceladus is assumed to be warmed from within as a result of the sort of tidal relationship with Saturn that keeps Jupiter's moons Io and Europa hot, but Enceladus otherwise differs markedly from those Jovian moons. Its surface is composed of regions of at least five significantly different ages, unlike Io and Europa, which have uniformly youthful surfaces. Heavily cratered regions on Enceladus are assumed to be several billions of years old. Younger regions resemble most closely the strangely grooved terrain on Ganymede, a Jovian moon that is not tidally heated and is some 2,000 times more massive than Enceladus.

□ An enormous trench on Tethys discovered by *Voyager 1* turns out to wrap two-thirds of the way around that Saturn moon. Like Mimas, Tethys is also now known to bear a supercrater with a diameter one-third that of the entire moon, and caused by an impact that must have been nearly big enough to shatter the whole body. But unlike the crater floor on Mimas, the floor of Tethys' supercrater has taken the moon's spherical shape, suggesting that the interior was once warm and soft enough to permit that deformation. (Without such warming, ice at such great distance from the sun would have the rigidity of steel.)

□ Hyperion is nonspherical, as are most of Saturn's small moons, and looks like a badly battered drum. But unlike all the other nonspherical moons, Hyperion fails to orient its longest axis toward Saturn. Some scientists speculate that an impact once knocked the moon from its expected natural orientation.—*Jim Loudon* □

a
Saturn from 5.8 million miles: a planet that is nothing but atmosphere—mostly hydrogen and helium, gaseous outside and compressed to a liquid below. It lacks a solid surface and its weather is driven mainly by the planet's internal heat, not the sun. The diagonal white ribbon is at 47° north latitude, where violent 300-mile-per-hour winds ceaselessly race eastward. An endless succession of highs and lows punctuates the wind belt, not unlike those that can be found at Earth's mid-latitudes. Between the wind ribbon and the calm region of ammonia clouds to the south is a necklace of vortices, such as the "figure 6" near the center. The field of the picture is about 40,000 miles. (*All photos from NASA Jet Propulsion Laboratory*)

b
Iapetus, Saturn's 900-mile-diameter, next-to-outermost moon—a "zebra" that is partly icy white and partly pitch black. The light portion is likely to be ice; the dark portion (actually about half the lunar surface) may be elemental carbon and/or hydrocarbon compounds. Gravity measurements suggest that the moon is predominantly composed of ice, with added methane.

c
Saturn's north polar regions showing thousands of small convective vortices (the two largest, near the center, are 150 miles across). Many may be the sites of ammonia rainstorms. The field of view is about 3,000 miles.

d
Saturn's equatorial region. Viewed from 750,000 miles, this region contrasts with the mid-latitudes by its lack of features. Cloud structures would be instantly torn apart by the 1,100-mile-per-hour winds—by far the greatest known in any gas of significant density anywhere. At the center, 49,000 miles closer to the camera than the clouds below, is the inner "shepherd moon," believed to influence the position of the F Ring, which is visible as a faint diagonal gray line.

e
Saturn's rings are actually remarkably different ringlets that vary systematically in color (no one is sure why), ranging from near ultraviolet closest to the planet to muddy orange farthest away.

Cowen/Continued from page 6

increasing opportunities for education as more self-study programs are programmed, but investing in a computer system for this purpose would still be a marginal decision for those on tight budgets.

Providers of these electronic services and the equipment to use them have fundamental work to do. Today the equipment, the software to use it, and the databank services still reek of their computer-science origins. Concepts of electronic files, data trees, even of computer commands are foreign and baffling to people outside the computer subculture.

At Britain's Cambridge University, the Medical Research Council's unit in applied psychology has been studying the interaction of "naive" users and computers. The researchers have found a widespread tendency for people to misunderstand the machines—they try to relate to the computer as though it were human and become frustrated when it doesn't respond or act "reasonably." As Nick Hammond of the team notes, "People have a view [of computers] very different from what programmers think they have." He adds, "The knowledge people bring to a problem is often in a different form from the way they have to present it to the computer."

"Naive" users eventually learn to cope. But what have they learned and how have they learned it? This is what the Cambridge team is trying to find out for there is no precedent in computer science or psychology to answer such questions. This kind of knowledge is necessary to develop really useful home computer services. A deep understanding of how people relate to computers and master them should be reflected in services, software, equipment, and instruction manuals.

Equally fundamental is the question of what services are truly useful and how best to supply them. Electronic mail will become widely useful only when it can be sent among databanks as well as within them. Hence, national standards must be set, and databanks themselves must be more easily accessible. They would probably be more useful to most people through TV, especially cable TV, with easy-to-use equipment—there really is no need for a complex, programmable computer.

There will probably be a host of imaginative and valuable uses for the home computer. But until they are defined, it is presumptuous to speak of a "revolution." John Morton says, "Man will have to modify himself to the computer." Perhaps that is true in the workplace. But when it comes to the home, why should we? ☐

Robert C. Cowen is science editor of the Christian Science Monitor *and former president of the National Association of Science Writers. He holds S.B. and S.M. degrees in meteorology from M.I.T.*

Boulding/Continued from page 4

really pays for the wage gains of successful unions? Often the answer is not the employer, who can pass on the increased wages by raising the price of the product, but rather the purchasers of the product on the one hand and the people who are excluded from employment on the other. Although there may be a real bargain between the two sides of a bargaining table, the people paying the bill are not there.

The air traffic controllers' strike is a tragic example of bargaining complexities. One may have every sympathy with the claim that it is a stressful occupation and that the employer-employee relationship is difficult. Furthermore, like truckers and night-working bakers, air-traffic controllers are removed from contact with the public they serve, making it difficult for them to develop a sense of community. Their separateness is further compounded by the fact that they work in buildings far from airports—they do not even see any planes.

We have here a case where the use of vague and unspecified threat and counter-threat makes everybody worse off. There is enormous opportunity for mutual misunderstanding and catastrophic decisions based on illusions about the future. How do we find an equivalent for the wonderful simplicity of the organized, fixed-price market in these complex political issues? I only wish I knew. ☐

Kenneth E. Boulding is a program director of the Institite of Behavioral Science and distinguished professor emeritus of economics at the University of Colorado at Boulder.

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Two Views on the Ca

Reduction at the Source

by Don G. Scroggin and Robert H. Harris

We must act now by conserving energy and accelerating the transition to renewable sources. Moreover, such measures are desirable in their own right.

A significant buildup of carbon dioxide in the earth's atmosphere, primarily from the increased burning of fossil fuels (coal, oil, and natural gas), may induce a global warming—via the so-called "greenhouse effect"—by the middle of the next century. This poses the risk of severe long-term changes in the global climate and the biological systems shaped by it; some have even called the CO_2 problem the most important long-term environmental issue confronting humanity. But although the changes expected in any particular region of the globe remain uncertain—altered precipitation and temperature may cause sizable and uneven shifts in agricultural patterns and thereby produce changes in social, economic, and political arrangements—a general scientific consen-
Continued on page 24

on-Dioxide Problem

A More Feasible Social Response

by Lester B. Lave

We must focus on adaptation to future climatic change instead of futile attempts to prevent it. Moreover, this approach is desirable in its own right.

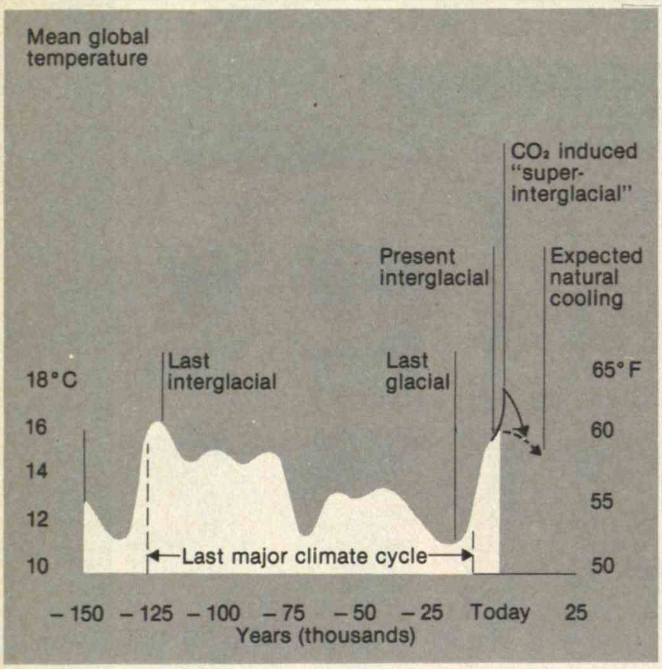
ATMOSPHERIC concentrations of carbon dioxide have been increasing for more than a century from human activities such as the clearing of forests and the combustion of fossil fuel. Because the latter will almost surely continue to accelerate in the foreseeable future, atmospheric concentrations will increase still further. According to various predictions, the increased carbon dioxide will warm the earth's climate, change precipitation patterns, and alter oceanic movements. However, the atmospheric changes will likely remain unmeasurable until at least the turn of the century and the effects will not be of substantial magnitude until well into the next century.

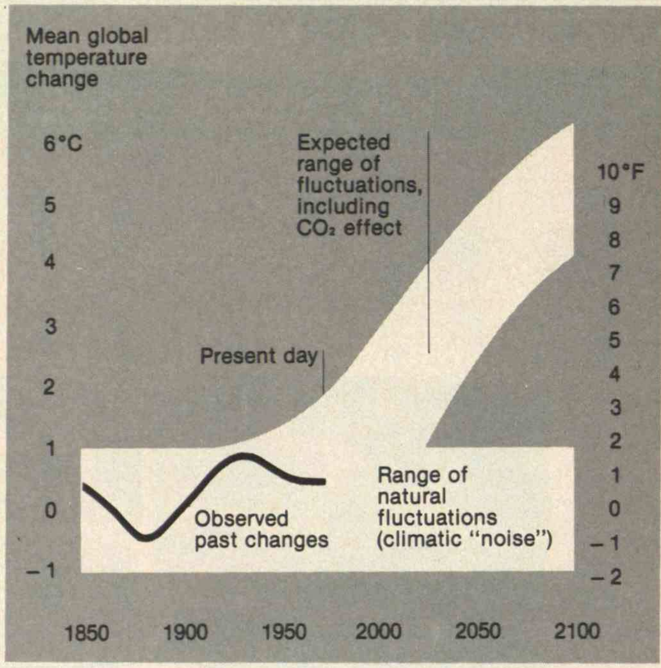
Uncertainty over four factors complicates efforts to examine the implications of increased carbon-dioxide

Continued on page 28

ILLUSTRATIONS: MICHAEL CRAWFORD

Below left: Projected CO_2 temperature disturbance in the context of Ice Age chronology of the past 150,000 years. Below right: Recent global-scale mean temperatures and their ranges of fluctuation, together with near-future projections with and without anticipated CO_2 effects. (Source: Elliott and Machta)





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sus has emerged that, given business as usual, significant CO_2-induced changes in global climate will eventually become manifest.

Reducing the growth in the global use of fossil fuels is an obvious response, but some scientists believe it may already be too late to avoid significant climatic changes. Instead, they urge policymakers to concentrate on *adapting* to these changes and mitigating their effects—by developing new strains of food crops better suited to warmer climates, for example. But such a view is too pessimistic; it underestimates human potential and assumes that continued global economic growth is inconsistent with a deemphasis on fossil fuels (and an emphasis on renewables). Moreover, many of the measures for limiting the growth of fossil-fuel use, quite apart from alleviating the risk of CO_2-induced climatic change, may be desirable for a host of economic, environmental, and national-security reasons as well. Futhermore, a policy of eventually limiting CO_2 atmospheric concentrations does not imply immediate reductions in total fossil-fuel use, but only in the rate of growth. Total fossil-fuel use could continue to grow well into the next century.

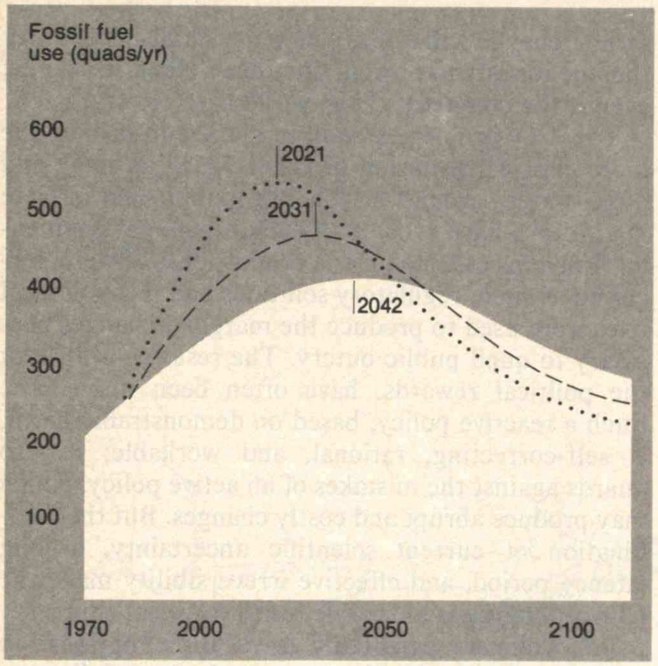
An Earthwarming Tale

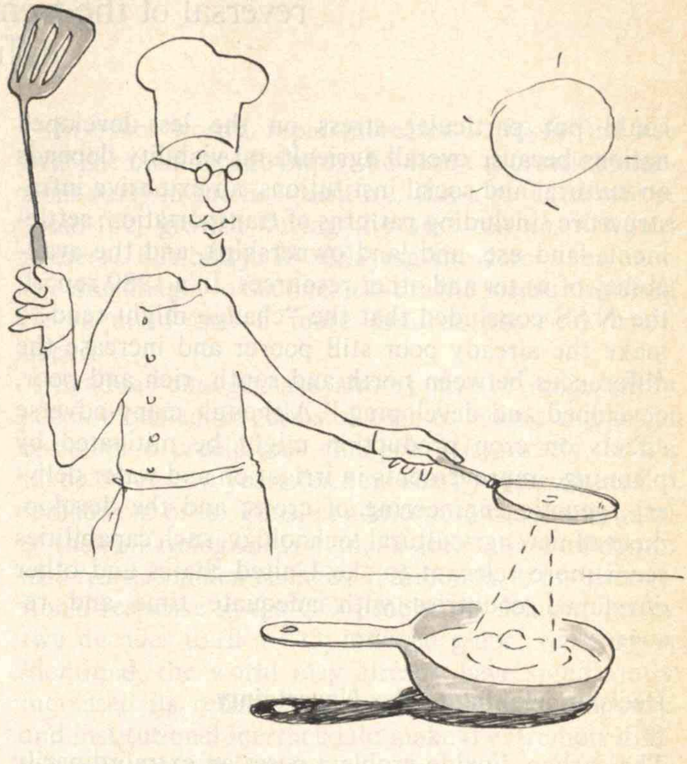
Carbon dioxide, normally a small component of the earth's atmosphere, is essential for maintaining the range of the earth's temperatures in which life has evolved. But most estimates of global energy use suggest that atmospheric CO_2 levels could reach twice the preindustrial level of about 290 parts per million within the next hundred years. If the warming were great enough, and persisted long enough to cause the breakup of the West Antarctic ice sheet, sea levels could rise five to eight meters in several decades. A five-meter rise in sea level would force a gradual evacuation of many coastline areas; in the United States alone, about 11 million people (5 percent of the population) would be directly affected.

In *Global Energy Futures and the Carbon-Dioxide Problem*, the president's Council on Environmental Quality made some extrapolations based on two commonly accepted assumptions: that the burning of fossil fuels will be the dominant source of CO_2 buildup, and that one-half of the CO_2 so produced is retained in the atmosphere. Thus, if global fossil-fuel use were to remain constant at today's level, a CO_2 doubling would not be expected until about the year 2175. With a 4 percent per year growth rate—the global figure for the 1940 to 1973 period—doubling would move forward to the year 2025. Data for 1973 to 1979 suggest that global fossil energy consumption has more recently grown by about 2.5 percent per year. If this average growth rate continues, a CO_2 doubling could occur by the middle of the next century.

There is little empirical basis for predicting the climatic consequences of increased atmospheric CO_2

Below left: The faster the global rate of growth of fossil-fuel combustion during 1980-1990, the sooner fossil-fuel use must peak if a CO_2 doubling is to be avoided. The solid curve represents an immediate but gradual response (from an initial 1.3% annual growth to 1.1% at decade's end), the dashed curve represents a constant 2.5% growth rate during the decade, and the dotted curve represents a constant growth rate of 4% (Source: Speth et al.)





concentration; the expected buildup of CO_2 is unprecedented in modern history. Therefore, the effect on the world climate from elevated CO_2 concentrations must be estimated from simulations—theoretical models. A 1979 review of these models by a panel of the National Academy of Sciences (NAS) reached conclusions that "may be comforting to scientists but disturbing to policymakers. . . . If carbon dioxide continues to increase, the study group finds no reason to doubt that climatic changes will result and no reason to believe that these changes will be negligible."

A CO_2 doubling is expected eventually to raise the average global surface temperature by about 3° C (the range of estimates is 1.5° to 4.5° C). This 3° temperature increase would move the world's temperature outside the range that has generally prevailed for the last several hundred thousand years (*see the chart on p. 24*). Furthermore, the temperature differences between the equatorial and polar regions—the primary driving forces of the earth's weather and climate systems—would likely change as well. The temperature changes caused by increased CO_2 concentrations are not expected to be uniform. Near the equator, a relatively smaller temperature increase should occur. In the high latitudes, especially the north polar region, a warming trend should be reinforced through a positive feedback effect: higher temperatures should reduce the highly reflective snow cover so that more of the incoming light is absorbed. The resulting average winter temperature in the high northern latitudes might rise as much as 7° to 10° C.

Several countervailing factors—such as clouds, dust, and natural cooling cycles—might be expected to reduce the effects of increased atmospheric CO_2. However, natural cooling cycles have historically occurred over thousands of years—much too slow to effectively counter the CO_2-induced warming expected in the next century. In any event, it now appears that cumulative cooling from any known countervailing factors will be modest. According to the NAS: "We have tried but have been unable to find any overlooked or underestimated physical effects that could reduce the current estimated global warmings due to a doubling of atmospheric CO_2 to negligible proportions or reverse them altogether. . . . It appears that the warming will eventually occur."

The impacts of CO_2-induced temperature changes on world agriculture might well be dramatic—agricultural production is critically dependent upon specific regional climatic factors such as temperature, humidity, and precipitation. Although growing seasons in some regions could be extended by the warmer climate, plant pests and diseases, which currently reduce the world's agricultural output by about 25 percent, could be favored by a warmer climate and thus further reduce agricultural productivity.

Even if the long-term climatic changes from increased atmospheric CO_2 did not cause net decreases in world food production, the short-term transitional effects could still be severe. Climatic change

If responses are delayed one or two decades until a global warming is identified, reversal of the trend may be extremely difficult.

could put particular stress on the less-developed nations because overall agricultural viability depends on cultural and social institutions, an extensive infrastructure (including patterns of transportation, settlement, land use, and land ownership), and the availability of water and other resources. In a 1980 report, the NAS concluded that the "change might tend to make the already poor still poorer and increase the differences between north and south, rich and poor, developed and developing." Although many adverse effects on crop production might be mitigated by planning, improvements in irrigation and water delivery, genetic engineering of crops, and the development of new agricultural technology, such capabilities seem more relevant to the United States and other developed countries with adequate time and resources.

Decision Making Under Uncertainty

The carbon-dioxide problem poses an extraordinarily difficult dilemma: To respond now to a threat with still-uncertain scope and timing might require unnecessary commitments of resources. But to postpone action until climatic change is detected entails the risk of being unable to prevent further harmful changes that could prove irreversible for centuries.

If today's most widely accepted models are correct, a CO_2-related global warming should be observable within the next two decades. Efforts to apply sophisticated detection techniques, even in the presence of the large amounts of "noise" from natural temperature fluctuations, are underway. One previous study based on indirect measurements suggests that a warming of as much as 0.4° C from CO_2 buildup may already have occurred between 1880 and 1970, but a clear warming trend has not yet been observed.

A CO_2-induced temperature increase might be delayed for one or two decades by the ocean's enormous capacity to absorb heat and large quantities of CO_2. The climatic changes should still occur, but much as a massive flywheel absorbs a large amount of energy as it gradually reaches a high speed, the oceans could substantially postpone the time when an increase in temperature could be detected.

Given the large momentum behind any climatic changes, remedial measures taken only after these effects were observed would be much less effective than any taken now. Thus, the policymaker's dilemma is that when the "signal" announcing the gradual global warming from CO_2 is finally identified, the pattern of change will already be well established. It may then be too late to prevent continued climatic change, even if the countries of the world agree to try.

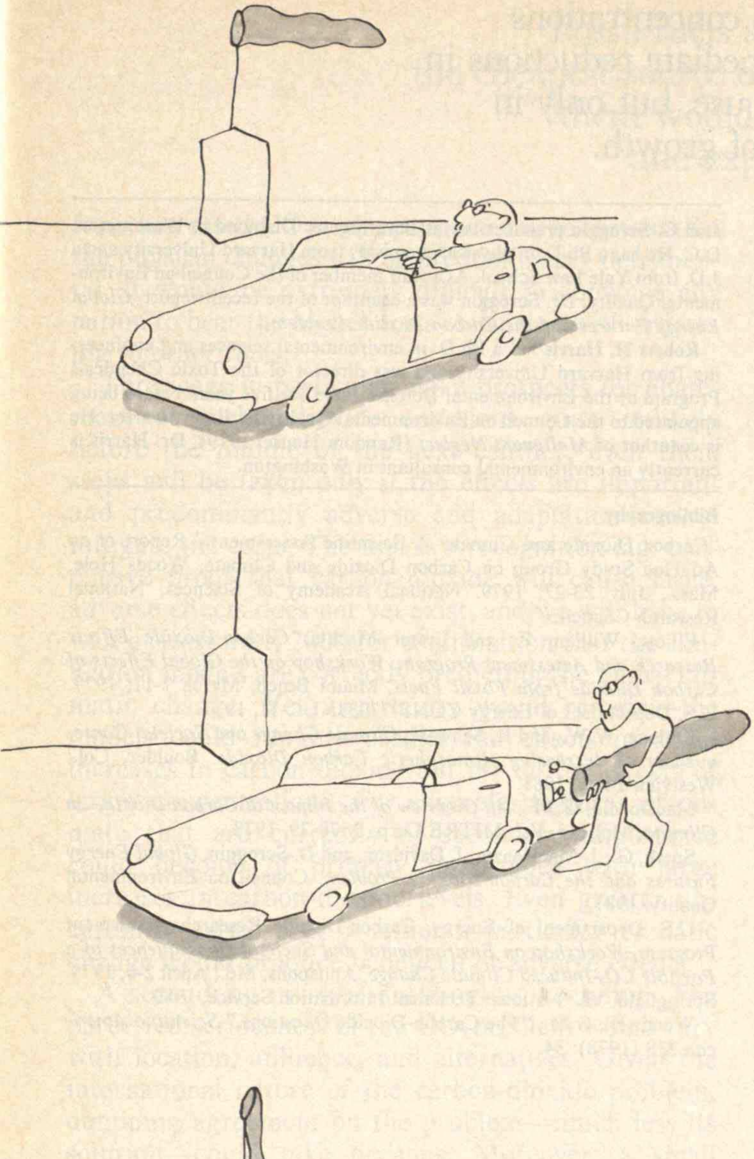
The CO_2 problem stands in stark contrast to the more classical pollution problems, such as smog and dirty water, around which our public and private institutions have evolved. As traditional environmental problems assumed crisis proportions, or were perceived as such, regulatory solutions and technological fixes were used to produce the marginal changes necessary to quell public outcry. The results, or at least the political rewards, have often been immediate. Such a reactive policy, based on demonstrable harm, is self-correcting, rational, and workable; it also guards against the mistakes of an active policy, which may produce abrupt and costly changes. But the combination of current scientific uncertainty, a long latency period, and effective irreversibility make the CO_2 problem less amenable to institutional control.

Policymakers essentially have three options: to establish an upper limit on atmospheric CO_2 by curtailing growth in fossil-fuel use, to take steps to adapt to the inevitable changes and mitigate the consequences, and to take no action until harmful impacts are observed. Although short-term political pressures appear to favor the last option, we believe a long-term strategy should focus primarily on the first two.

A growing number of analysts espouse the second option, but what they often overlook is that many of the measures inherent in the first option are desirable whether or not climatic changes actually occur. Such measures include energy conservation and the development of renewable energy sources. If control of CO_2 is considered an insurance policy, the "premium" (net cost of deemphasizing fossil fuel) is low or negative (a dividend) because the activities it comprises are economically attractive, pose little environmental hazard, and reduce dependence on imported oil.

Strike Before the Earth Is Hot

Under the assumption that the world community will eventually be driven to limit atmospheric CO_2 to avoid harmful climatic changes, the rate of growth in fossil-fuel use during the next decade will critically affect the world's flexibility at that time. This is the general conclusion of the previously mentioned CEQ report, and there are two specific corollaries for policymakers. First, the higher the rate of fossil-fuel use during the next two decades, the earlier total global fossil-fuel use must peak. Thus, the more rapid the increase



now, the sooner must be its reduction. For example, in scenarios leading to a CO_2 doubling, moderate (2.5 percent) to high (4.0 percent) growth rates in fossil-fuel use over the next 10 years require a decline in the burning of fossil fuels 10 to 20 years sooner than if only modest (initially, 1.3 percent) growth occurred during the next decade. Second, an earlier peak in fossil-fuel use requires a steeper decline following that peak (*see the figure on p. 25*).

In other words, rapid increases in fossil-fuel use over the next decade imply the need for drastic reductions early in the next century. But a reduced rate of fossil-fuel growth during the next ten years would preserve flexibility. By delaying the date when such use must begin to decline, less drastic measures would be required and a more gradual phaseout could occur.

Gradual changes are almost always more easily accommodated, in terms of both economic and social costs, than precipitous changes. Historically, it has taken 50 to 100 years for new energy technologies to replace old ones. Thus, in addition to the momentum of the climatological system, an economic momentum also resists sudden changes in direction. If an international response to the CO_2 problem is delayed one or two decades until a CO_2-induced global warming is identified, the world may already have significantly increased its reliance on fossil fuels, and economic and institutional inertia could make it extremely difficult to reverse this trend.

The conclusion for long-term planners can thus be simply stated: a lower growth rate of fossil-fuel use over the next few decades, combined with a more efficient use of energy, would reduce the pressures for rapid societal and technological change later on and allow more time for development of alternative energy sources. Conversely, a more rapid increase in fossil-fuel use during the next decade might necessitate an earlier and more drastic reduction.

Setting an Example

The global nature of the CO_2 problem demands international cooperation of unprecedented coordination. The difficulty is compounded by the probable inequalities of CO_2-induced changes—there will be winners and losers. Some nations may benefit from the new climate and be understandably reluctant to cooperate in a global effort to reduce CO_2 emissions—particularly if the "winner" nation is a developing country that plans to greatly expand its per capita energy consumption. (The developed nations currently account for only 30 percent of the world's population but for more than 80 percent of the world's total commercial energy consumption. Over the coming decades, developing countries could become the fastest-growing sector in the world's energy economy.)

But the Third World's economic growth can be consistent with international measures to control CO_2 buildup. The great potential for energy conservation

Limiting CO_2 concentrations does not imply immediate reductions in total fossil-fuel use, but only in the rate of growth.

in the developed nations can offset the fossil-fuel use in the less-developed nations to allow them to grow. Such a balance could continue well into the next century, with total global CO_2 emissions still under control. Moreover, high levels of energy efficiency and reliance on renewable energy sources could be incorporated into the economies of developing countries, thus providing assurance that their energy and economic systems would not later require the major overhaul now necessary in the developed countries.

To forge an international response to an intangible problem with still-uncertain consequences is no easy task. But the United States and other industrialized nations can set an example through energy planning. The developed nations can demonstrate to the rest of the world that a decreased reliance on conventional energy sources, together with an increased application of conservation and renewable energy sources, are consistent with a growing and prosperous economy.

Even without the risks of climatic change, the more basic considerations of economics, national security, and other environmental harm offer persuasive arguments for a global policy to deemphasize dependence on fossil fuel and emphasize energy efficiency and renewable sources. With the risk of potentially disastrous CO_2-induced climatic changes added to the picture, these arguments are all the more compelling.

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Bibliography

"Carbon Dioxide and Climate: A Scientific Assessment." Report of an Ad Hoc Study Group on Carbon Dioxide and Climate, Woods Hole, Mass., July 23-27, 1979. National Academy of Sciences, National Research Council.

Elliott, William P., and Lester Machta, *Carbon-Dioxide Effects Research and Assessment Program: Workshop on the Global Effects of Carbon Dioxide from Fossil Fuels*, Miami Beach, March 7-11, 1977. U.S. Department of Energy CONF-770385 UC-11, 1977.

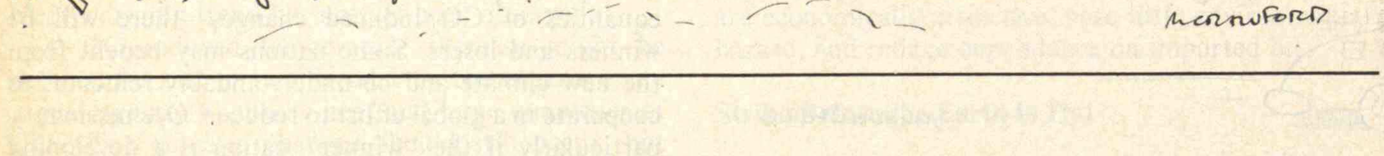
Kellogg, W.W., and R. Schware, *Climate Change and Societal Consequences of Increasing Atmospheric Carbon Dioxide*. Boulder, Col.: Westview Press, 1981.

MacDonald, G.J.F., *An Overview of the Impact of Carbon Dioxide on Climate*. McLean, Va.: MITRE Corp., M78-79, 1978.

Speth, G., J. MacKenzie, J. Davidson, and D. Scroggin, *Global Energy Futures and the Carbon-Dioxide Problem.* Council on Environmental Quality, 1981.

U.S. Department of Energy, Carbon-Dioxide Research Assessment Program, *Workshop on Environmental and Societal Consequences of a Possible CO_2-Induced Climate Change*, Annapolis, Md., April 2-6, 1979. Springfield, Va.: National Technical Information Service, 1980.

Woodwell, G.M., "The Carbon-Dioxide Questions." *Scientific American* 238 (1978): 34.



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emissions: the amount of fossil fuel that will be burned each year (depending on world population, economic activity, the costs and availability of each energy source, and technologies for utilizing energy); the resulting changes in the atmosphere, the polar ice caps, and the oceans; the ecological responses; and the extent to which humans can mitigate the adverse effects of the changes or even utilize them to better accomplish individual and social goals.

A Virtual Inevitability

Policies designed to lessen carbon-dioxide emissions are inherently unattractive. Fossil fuels are currently the cheapest source of energy; proscribing them would be difficult and expensive. And since we can neither estimate the magnitude of global changes

Fossil fuels are currently the cheapest source of energy; proscribing them would be difficult and expensive.

from increased CO_2 with assurance nor be certain that the physical changes will be predominantly detrimental, it would be extremely difficult to convince any nation to bear the higher costs associated with switching to other fuels.

Three lags in particular make prospects for abatement of carbon-dioxide emissions quite unlikely before the middle of the next century; even then, steps will be taken only if the effects are important and predominantly adverse and adaptation cannot mitigate the costs. The first is a recognition lag: conclusive proof that carbon dioxide will cause large, adverse effects does not yet exist, and we will have to wait at least until 2000 for confirmation that the simulation models are correctly predicting the global climatic change. Yet uncertainty would remain—the models could roughly predict the effects of small increases in carbon dioxide but err on the effects of larger concentrations. For example, features of climate that are currently of secondary importance could become of primary importance with large increases in carbon-dioxide levels. Even greater uncertainty arises over whether a particular climatic change would produce beneficial or adverse effects.

A second lag involves deciding on a solution. The perceived seriousness of the CO_2 problem would vary with location, affluence, and alternatives. Given the international nature of the carbon-dioxide problem, obtaining agreement on the problem—much less its solution—could take decades. Moreover, a small nation's abatement program would not noticeably affect climate, and some nations who stand to gain from climatic change might actually *encourage* fossil-fuel burning.

Finally, assuming that worldwide agreement were reached on policies, there would be a third lag in switching to alternative fuel sources, a decades-long proposition.

The three lags are likely to be so long that carbon-dioxide emissions could not be substantially curtailed until the latter part of the next century. Without other compelling reasons for relinquishing fossil fuels, therefore, it seems virtually certain that substantial climatic change from CO_2 will occur and persist. Thus, if society is to do something about this potential problem, the emphasis should be on adapting to it.

Subtle Cues, Implicit Adjustments

Conscious adaptation is a thoughtful response by an institution or individual to a perceived problem or need for change. The action can result from legal compulsion or spontaneous recognition, but in both cases behavior is modified through widespread dissemination of information. Climatic change could affect investment decisions, education and training, migration and location generally, jobs, and the production and purchase of goods and services. Explicit government intervention to change behavior might take the form of laws, licensing, zoning, and control of conditions of operation. But mitigating the problems caused by carbon dioxide is likely to require subtle changes in individual behavior that could not be induced by such regulation. The pertinent facts, the people to be reached, and the points of leverage all vary with each target.

A range of other possible governmental actions, such as taxes, subsidies, and attempts at moral suasion, do not compel changes in behavior but do exert an influence. Although these actions stem from conscious decisions by government, they need not result in conscious decisions by consumers.

Taxes and subsidies can provide various degrees of incentive to change behavior, but implementation is difficult and applicability is limited. More important, there is the temptation to use taxes, subsidies, and licenses to reward special groups or accomplish unrelated, often socially undesirable goals. Economists have learned painfully that subsidies and regulations are predominantly political processes with outcomes that usually have little semblance of economic efficiency.

But the government's power of moral suasion should not be underestimated. When not against an individual's perceived self-interest, moral suasion can lead to important changes in behavior. Even if individuals are required to make sacrifices, most will do so provided there is a perceived threat to society and a belief that all individuals will share the burden. Examples of such actions include service in the armed forces during wartime or conservation of water and energy during crises. If people were convinced that carbon dioxide is a serious problem, they would probably respond to appeals to conserve energy.

More important than conscious adaptation, however, is implicit or automatic adjustment. For example, adjustment to changes in consumer preferences for goods and services is done automatically via prices and profits in the marketplace. The market provides unmistakable signals in the form of crop failures, unemployment, and bankruptcy, or more subtlely in the form of lower wages and profits for some busi-

The ability to adapt to carbon-dioxide-induced changes will be determined by our general ability to adapt to social and economic change.

nesses compared with profit increases and higher wages for others. Closely related are social structures and pressures that affect family size, economic activity, geographic location, and consumption patterns and indirectly affect CO_2 emission rates and adaptability to climatic change.

Unconscious adaptation is the translation of subtle cues into individual and social change. But whether such adaptation is helpful to a community, a nation, or the world depends on the aggregation of individual actions. Ultimately, the institutional and technological structures of society determine whether individuals acting in their self-interest will speed or impede social adjustments. The economic model of perfect competition, for example, is one institutional framework wherein individual actions are perfectly consonant with social obligations.

Adaptation for All Seasons

Carbon-dioxide-induced environmental changes may require the relocation of businesses, residences, and social-overhead capital such as streets and sewers. Plant and equipment may have to be replaced and workers may be obliged to find new jobs, which often require new skills. Firms may have to redesign their products and manufacturing processes. Yet these changes will accompany other, more profound changes caused by shifts in taste, technological innovation, the availability of raw materials, and patterns of international trade and relations, as well as "normal" climatic variations. The ability to adapt to the carbon-dioxide-induced changes will be determined by our ability to adapt to these other changes.

Will the automatic mechanisms send the proper signals? Will governmental and other decision makers perceive the problem and implement policies to expedite adaptation? If people perceive the need to change their behavior, will they have the resources and knowledge to do so? Will social and economic institutions be able to keep pace with climatic and social change? In other words, will our social and economic institutions respond to the changing conditions or break down under the pressure?

Whether society will have the required resources to adapt will be measured by several indicators. The first is gross national product (or income) per capita. This is a measure of aggregate economic activity and a surrogate for the economic resources available to build new facilities or move people. (The precise variable is "free" economic resources per capita. A poor society, such as a nomadic one, might be able to adapt more easily than a rich society unwilling or unable to direct resources to implement needed changes.)

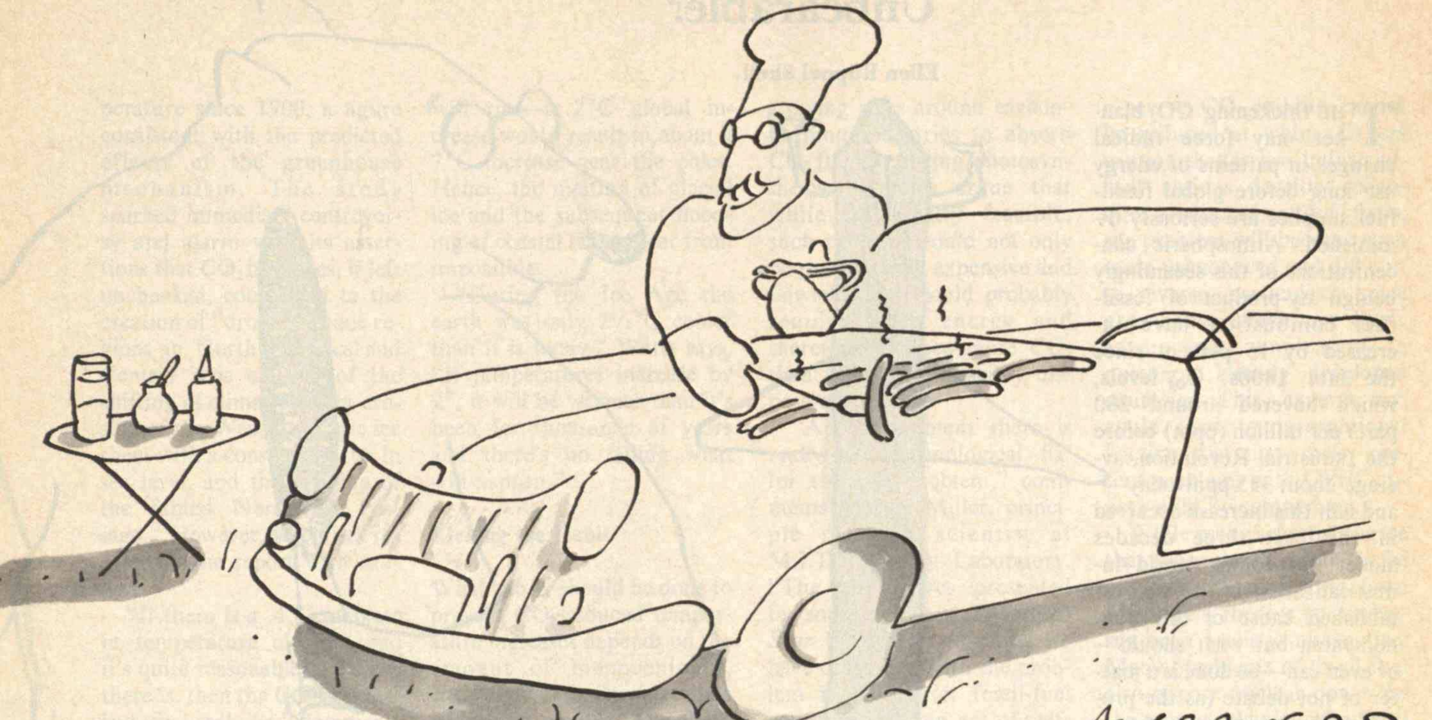
The second indicator is the gross rate of investment, or ratio of investment to GNP. A high ratio means that the economy is putting many new facilities into place and turning over its capital stock rapidly. Since plant and equipment can be designed for the new situations and be built in the right places, rapid turnover means that most capital would be tailored to the new regime. For example, consider an economy in which capital lasts 50 years—only 2 percent is replaced each year. Although climatic change could make much of the capital obsolete, it would remain in place for a long time. In contrast, an economy that turns over its capital stock rapidly—say, every decade—could better respond as changes were perceived.

A third measure of an economy's capacity to adapt is the general educational level of workers. Well-educated workers can better redesign products and facilities to respond to new conditions, and they find it easier to acquire the skills needed for new jobs.

Other characteristics facilitating adaptation are not so simple to measure. One is the flexibility and diversity of capital stock. Some plant and equipment are so highly specialized that minor changes in raw materials, product design, or fuels are impossible to accommodate. Some oil refineries, for example, were built to process only one type of crude oil and produce a fixed set of outputs. A counterexample is an electrical generating unit that burns oil, coal, natural gas, any two, or even all three fuels at once. Diversity of the capital stock also gives the economy the resiliency to avoid disaster in the face of changing external conditions such as climate. However, flexibility generally entails higher capital cost and lower efficiency.

Another vital but difficult-to-measure characteristic is the level of basic scientific knowledge, which can be used to increase the number of technological alternatives currently available or that can be quickly developed. And another, related characteristic is the capacity of individuals to interpret the signals of changing conditions correctly and adapt to them—in both cases by using the available tools.

Society should take steps to enhance each of these characteristics so that we have the ability to adapt more easily to carbon-dioxide-induced changes. But note that each attribute (with the possible exception of data collection and analysis focused on climate) benefits society generally and is not unique to carbon-



dioxide-induced problems. Carbon-dioxide buildup can provide a rationale—but more probably it will be a catalyst—for enhancing society's ability to adapt to and exploit a changing environment. The issue is but one of many that will have an enormous impact on the world economy and social institutions in the twenty-first century, and it provides one more argument to make these institutions flexible, adaptable, and strong.

References

Council on Environmental Quality, *Global Energy Futures and the Carbon-Dioxide Problem*. Government Printing Office, Janaury 1981.

Epple, Dennis, and Lester Lave, "Planning for Climate Change: Scenario Construction and Evaluation." American Association for the Advancement of Science, 1980.

Flohn, H., *Possible Climatic Consequences of a Manmade Global Warming*. International Institute for Applied Systems Analysis, December 1980.

Maddan, R., and V. Ramanathan, "Detecting Climate Changed Due to Increasing Carbon Dioxide." *Science* 209, 4458 (August 15, 1980).

Manabe, Syuko, and R.T. Wetherald, "The Effects of Doubling the CO_2 Concentration on the Climate of a General Circulation Model." *Journal of Atmospheric Sciences* 32 (1975).

Manabe, Syukuro, and Ronald J. Stouffer, "Sensitivity of a Global Climate Model to an Increase of CO_2 Concentrations in the Atmosphere." *Journal of Geophysical Research* 85 (October 20, 1980).

Meyer-Albich, Klaus M., "Chalk on the White Wall? On the Transformation of Climatological Facts into Political Facts." In *Climate Constraints and Human Activities*, Jesse Ausubel and Asit K. Kiwas, eds. Oxford: Pergamon Press, 1980.

National Academy of Sciences, *Carbon Dioxide and Climate: A Scientific Assessment*, 1979.

Nordhaus, William, "Thinking About Carbon Dioxide: Theoretical and Empirical Aspects of Optimal Control Strategies." Yale University working paper, July 1980.

Olson, Mancur, "A Conceptual Framework for Research About the Likelihood of a Greenhouse Effect." University of Maryland working paper, July 1980.

Proceedings of the Carbon Dioxide and Climate Research Program Conference. U.S. Department of Energy, Carbon-Dioxide Effects Research and Assessment Program, CONF-8004110, December 1980.

Revelle, R., E. Boulding, C.F. Cooper, L. Lave, S. Schneider, and S. Wittwer, *Environmental and Societal Consequences of CO_2-Induced Climate Change: A Research Agenda*. Department of Energy, DOE/EV/10019-01, December 1980.

Robinson, Jennifer, and Jesse Ausubel, "A Framework for Scenario Generation for CO_2 Gaming." International Institute for Applied Systems Analysis, March 1981.

Schelling, "The Ecology of Micro Motives." *Public Interest* 25 (1971): 61-98.

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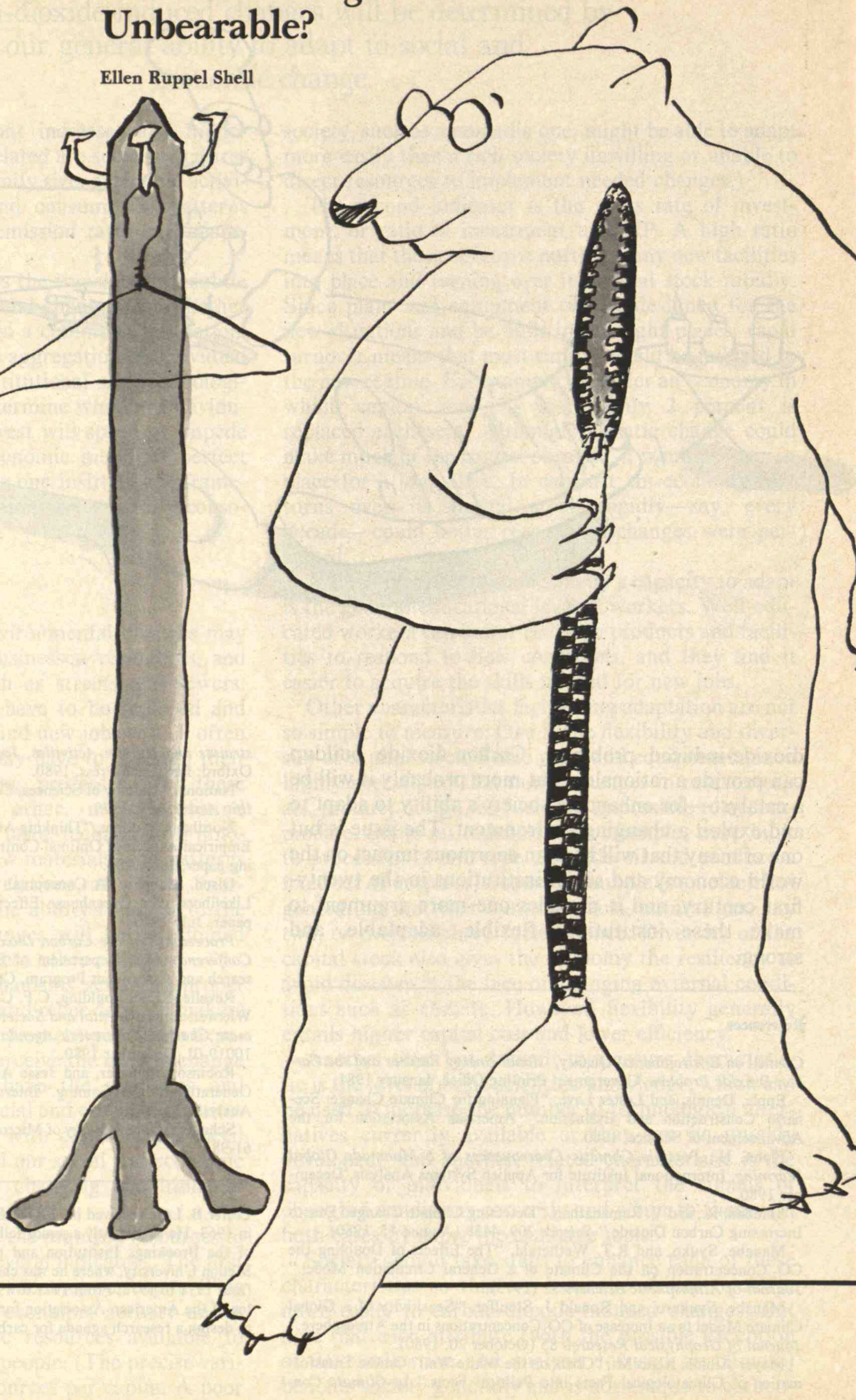
Will the Changes Be Unbearable?

Ellen Ruppel Shell



THE thickening CO_2 blanket may force radical changes in patterns of energy use long before global fossil-fuel supplies are seriously diminished. Atmospheric concentrations of this seemingly benign by-product of fossil-fuel combustion have increased by 15 percent since the late 1800s. C_{O2} levels, which hovered around 280 parts per million (ppm) before the Industrial Revolution, average about 335 ppm today—and half this increase occurred in the past three decades alone. Burgeoning world industrialization is the well-established cause of this phenomenon, but what should—or even can—be done is a matter of hot debate (as the preceding discussions attest).

CO_2 is an active gas that absorbs infrared radiation reflected from the earth and lower atmosphere. Hence, it acts like the glass in a greenhouse to retain heat energy and cause earth temperatures to rise—the notorious "greenhouse effect." Researchers at Brookhaven National Laboratory and elsewhere estimate an increase of two to three degrees in global temperature for every doubling of atmospheric CO_2 concentrations over preindustrial levels. However, little hard data were available to support this hypothesis until last August, when an article in *Science* reported that a significant increase in world temperatures had already occurred.

Written by atmospheric physicist James E. Hansen and his team at the NASA Institute for Space Studies at Goddard Space Flight Center in New York City, the paper gave systematic evidence of a .4°C increase in global tem-

perature since 1900, a figure consistent with the predicted effects of the greenhouse mechanism. The study sparked immediate controversy and alarm with its assertions that CO_2 increases, if left unchecked, could lead to the creation of "drought-prone regions in North America and Central Asia as part of the shifting of climatic zones, erosion of the West Antarctic ice sheet with a consequent rise in sea level, and the opening of the fabled Northwest Passage." However, scientists reacted to the report with caution.

"If there is a .4°C increase in temperature already, and it's quite reasonable to believe there is, then the CO_2 problem is a very real one," comments Robert Watts, professor of mechanical engineering at Tulane University and a consultant at the Institute of Energy Analysis in Oak Ridge, Tenn. "But detecting such an increase is terribly difficult because of fluctuations caused by natural background effects."

However, Watts adds that all models have shown that a two-to-three-degree increase in world temperatures is "inevitable if we continue to burn fossil fuels at our present rate." Such an increase would not turn Buffalo into a tropical resort area, but it would have a significant impact on world agriculture and climate. Scientists predict that the most serious effect would be a change in rainfall patterns that could turn northern Canada into a very lush farm area, while rendering the American prairies as dry as the Dust Bowl of the 1930s. The further an area is from the equator, the more its temperature will rise—a 2°C global increase would result in about a 7°C increase near the poles. Hence, the melting of glacial ice and the subsequent flooding of coastal cities is far from impossible.

"During the Ice Age the earth was only 2½°C cooler than it is today," Watts says. "If temperatures increase by 2°, it will be warmer than it's been for thousands of years and there's no telling what will happen."

Kicking the Habit

What can or should be done to prevent CO_2-induced temperature increases depends on the amount of inconvenience, cost, and setback society is willing to endure. The measures offered by a panel of scientists at a recent meeting of the American Chemical Society (ACS) in New York all necessitated either a sharp reduction in fuel consumption or a steep increase in energy costs—highly unpopular alternatives. However, panel member Meyer Steinberg of Brookhaven pointed out that a technique that may seem extravagant by today's standards could prove a bargain in the future. "Economics," he said, "is a moving target."

One of Dr. Steinberg's more novel proposals was to pump CO_2, chemically "scrubbed" from exhaust in smokestacks, into depleted oil wells where the resulting increase in pressure would force untapped reserves to the surface, thereby enhancing oil recovery. Another, perhaps more romantic, notion was originally researched by Freeman Dyson of Princeton's Institute of Advanced Study several years ago: plant fast-growing trees around carbon-burning industries to absorb CO_2 for use during photosynthesis. Skeptics argue that while technically feasible, such projects would not only be prohibitively expensive and unwieldy but would probably require more energy and therefore produce more CO_2 than they could possibly dispose of.

"At the moment there is really no 'technological fix' for the CO_2 problem," comments Marvin Miller, principle research scientist at M.I.T.'s Energy Laboratory. "The alternatives presented by some are straight out of *Star Wars*. The only way we have of dealing with the problem is to restrict fossil-fuel consumption," an act of self-discipline he admits will be particularly difficult in light of the conclusion of the international World Coal Study, published last year, that massive coal reserves in the United States, Soviet Union, and People's Republic of China could serve as the "bridge to our energy future" (*see "A Shaky Crossing," p. 12*). Miller says models show that if all available coal reserves were burned for fuel, atmospheric CO_2 levels could theoretically go as high as 1200 ppm—a decidedly unhealthy concentration.

While the authors of the coal-study report acknowledge this possibility and suggest that it be studied more fully, they contend that there is no evidence to "justify limiting fossil-fuel use." Miller warns that this is unrealistic: "If we start burning the coal now, and discontinue burning when serious problems begin to surface, we'll have waited too long," he says, adding that a severe CO_2 buildup cannot be reduced at whim. Others caution that as less-industrialized nations develop economies predicated on fossil fuels, the problem will become even more pronounced and difficult to reverse, particularly since greenhouse effects are likely to be most unpleasant in northern, already developed countries. This, experts say, could lead to international friction that may make present problems with OPEC appear mild by comparison.

While many scientists agree that there should probably be a gradual transition away from fossil fuels, there is no consensus on a realistic alternative. Many opponents of fossil fuel also oppose nuclear power on the grounds that it—like fossil fuels—presents no ready technological fix for the potential problems it poses. But most also admit that renewable sources such as solar, wind, and tidal power are a long way from becoming viable on a large scale.

"We simply can't stop burning fossil fuels immediately—the economy won't stand for it," says Greg Marland, a staff geologist at Oak Ridge Laboratory who participated in the ACS panel. "But if Hansen's .4°C increase is born out, we're in for some serious problems. I guess it comes down to the same old scientists' plea—a good deal more study needs to be done before any firm recommendations can be made. Though even if we fully understood the extent of the CO_2 problem right now, I'd doubt anyone could really tell us what to do about it."

Ellen Ruppel Shell is senior editor of Technology Review.

WHAT TO DO WITH HAZARDOUS WASTE

by Selim M. Senkan and Nancy W. Stauffer

Toxic and hazardous chemical wastes, the inevitable by-products of a technological society, rank as one of our most serious problems. But proper management practices can prevent them from threatening life or its environment.

FOR many decades industrialized society has produced hazardous chemical wastes. They threaten human health and the environment because they have dangerous properties; many are toxic and some can explode or undergo destructive reactions. In the 1970s a series of highly publicized incidents began linking human tragedy with hazardous wastes handled improperly in the past, either through negligence or lack of knowledge. People became terrified of waste-disposal sites, viewing them as time bombs. The fragile nature of our environment became clear, but much damage had already been done.

Meanwhile, industrial and other activities continued to produce billions of pounds of potentially hazardous wastes. Responding to growing concern, many companies adopted the safest waste-handling techniques available, and some began to invest substantial funds into improving current technologies and developing new ones. Unfortunately, some companies continued to handle their wastes irresponsibly. After all, the economic incentive is great: it costs ten to a hundred times more to use proper waste-treatment methods than simply to dump untreated wastes in unsecured landfills, rivers, lakes, and oceans. The prices

charged by companies using unsafe methods did not reflect the full social cost of production, and the conscientious producers found themselves at a serious competitive disadvantage. Recognizing the economic pressures within industry and the potential dangers posed by hazardous wastes, the federal government began to take legal and political steps to ensure better waste management.

However, developing sound waste-management policies has proved controversial and complex. The Resource Conservation and Recovery Act (RCRA) of 1976 gives the U.S. Environmental Protection Agency (EPA) overall responsibility for setting hazardous-waste regulations and assigns individual states responsibility for developing specific hazardous-waste programs. Both tasks have been difficult. After considerable effort, EPA published its first set of rules and regulations in May of 1980, including criteria for identifying hazardous and toxic wastes, a list of specific and nonspecific hazardous-waste streams, and a manifest system for controlling them from production to disposal ("cradle-to-grave").

Industry immediately criticized the regulations as expensive and stifling, calling for—at a minimum—added provisions establishing "degree of hazard." (Under the current system, all substances that fit EPA's broad definition of "hazardous" are subject to the same rules.) EPA is trying to respond to industry's demand, but developing an acceptable scheme may be impossible: the agency had considerable difficulty just creating a broad definition (*see page 40*).

While EPA and industry continue their controversy, the states have problems of their own. Many states want or need regulations stricter than those set by EPA, but while they have the legal right to set stricter laws, they might find it impossible to enact them without federal backing (*see page 48*). Like environmental groups, the states are worried about the Reagan administration's steps to cut EPA's budget and ease current regulations in an attempt to improve the economy.

The Federal Perspective

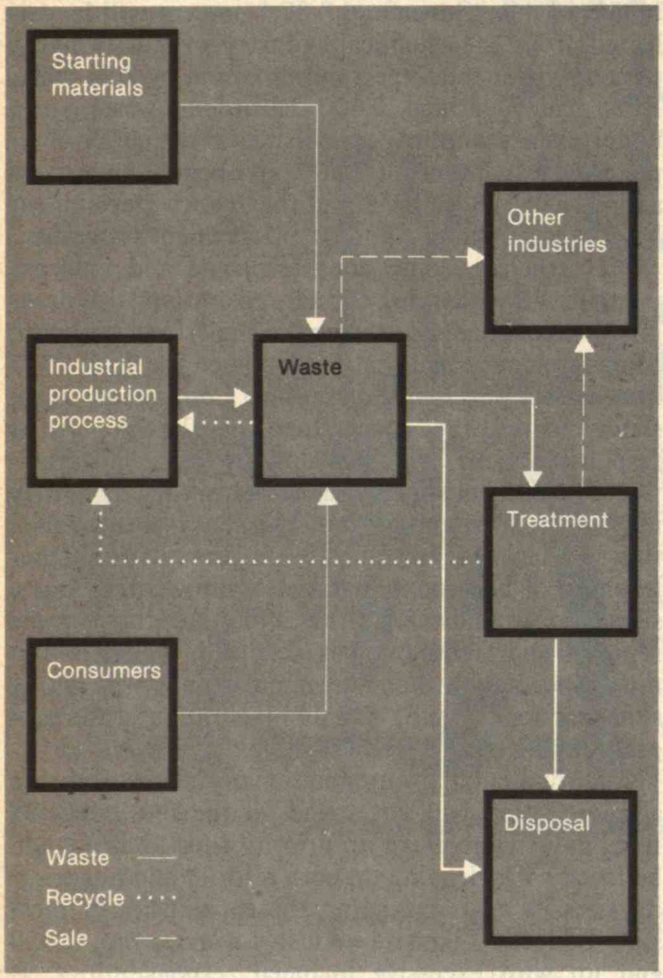
Despite those steps, the Reagan administration claims that the cleanup of hazardous spills and dumpsites is its highest priority. Such cleanup activities are covered by the Comprehensive Environmental Response Act of December 1980, which establishes a trust fund to pay for cleanup of waste sites and spills and assigns EPA responsibility for administering it. Of the $1.6 billion in this "Superfund," 87.5 percent will be collected from the chemical industry over a five-year period. Under the Superfund program, by July 1981, EPA had identified 9,300 hazardous waste sites, undertaken preliminary assessments of 5,900, completed investigations of 2,700, and begun emergency actions at 52. Both EPA and the Justice Department have been pursuing vigorous enforcement programs.

Nevertheless, some congresspeople and environmentalists are charging the administration with dragging its feet in administering the Superfund program. Many are concerned that EPA missed the June 1981 deadline for developing a National Contingency Plan, slated to be the cornerstone of the Superfund response actions. Furthermore, EPA has not completed a uniform scheme for states to rank sites they identify as threatening. And emergency actions taken thus far have focused mostly on preventing further leaching of hazardous materials from existing waste sites into groundwater; little actual hazardous-waste removal and treatment has occurred. There is also much speculation that Superfund money will not be sufficient for cleanup, with administration of the program taking most of the funds.

Environmental groups and many states fear the administration will not spend all the fees collected from industry to clean up priority sites. States could be faced with cleaning up both priority and nonpriority sites—a task exceeding the capabilities of most state budgets. Likewise, industry worries that it will end up with excessive financial responsibilities. If EPA judges a company's cleanup efforts inadequate, the agency will do the work and bill the company three times its expenses. But when a company cleans up its own sites, there is no limit on its cleanup responsibilities—no definition of what is "adequate."

The crux of the hazardous-waste regulation problem is clear: we do not have enough solid scientific information to identify with certainty the "right" level of regulation. And it is not surprising that battles are highly emotional: too much regulation can severely impair our economic well-being, while too little regulation can threaten our very lives. Nevertheless, we must not let the regulatory furor obscure one encouraging fact: while we may not fully understand all aspects of the hazardous-waste issue, we do have the basic technology to handle most waste-related problems. Many of the processes are expensive, but their costs are outweighed by the potential gains associated with saving human lives, decreasing human

To manage hazardous wastes, the general pathways of industrial waste generation, recycle, and disposal must be considered. The best solution includes reducing the initial quantity and danger of hazardous wastes, and many industries are modifying their processes to accomplish this source reduction. Wastes can also be recycled or reused; what's left must be treated and disposed of in an environmentally acceptable way.



CHARTS: OMNIGRAPHICS

suffering, and protecting our environment from toxic chemical contamination. Also, research is underway in government, industry, and academia to improve the technology, and the prospects for even more effective, less costly methods of treatment and disposal are good.

The Magnitude of the Problem

According to EPA's definition, between 10 and 17 percent of all chemical wastes are "hazardous"—some 35 to 60 million metric tons (77 to 130 billion pounds) in 1980. Although some toxic substances are now being banned, production of chemicals is increasing and new materials are being identified as hazardous, resulting in a 5 to 10 percent growth in the amount of hazardous wastes generated each year.

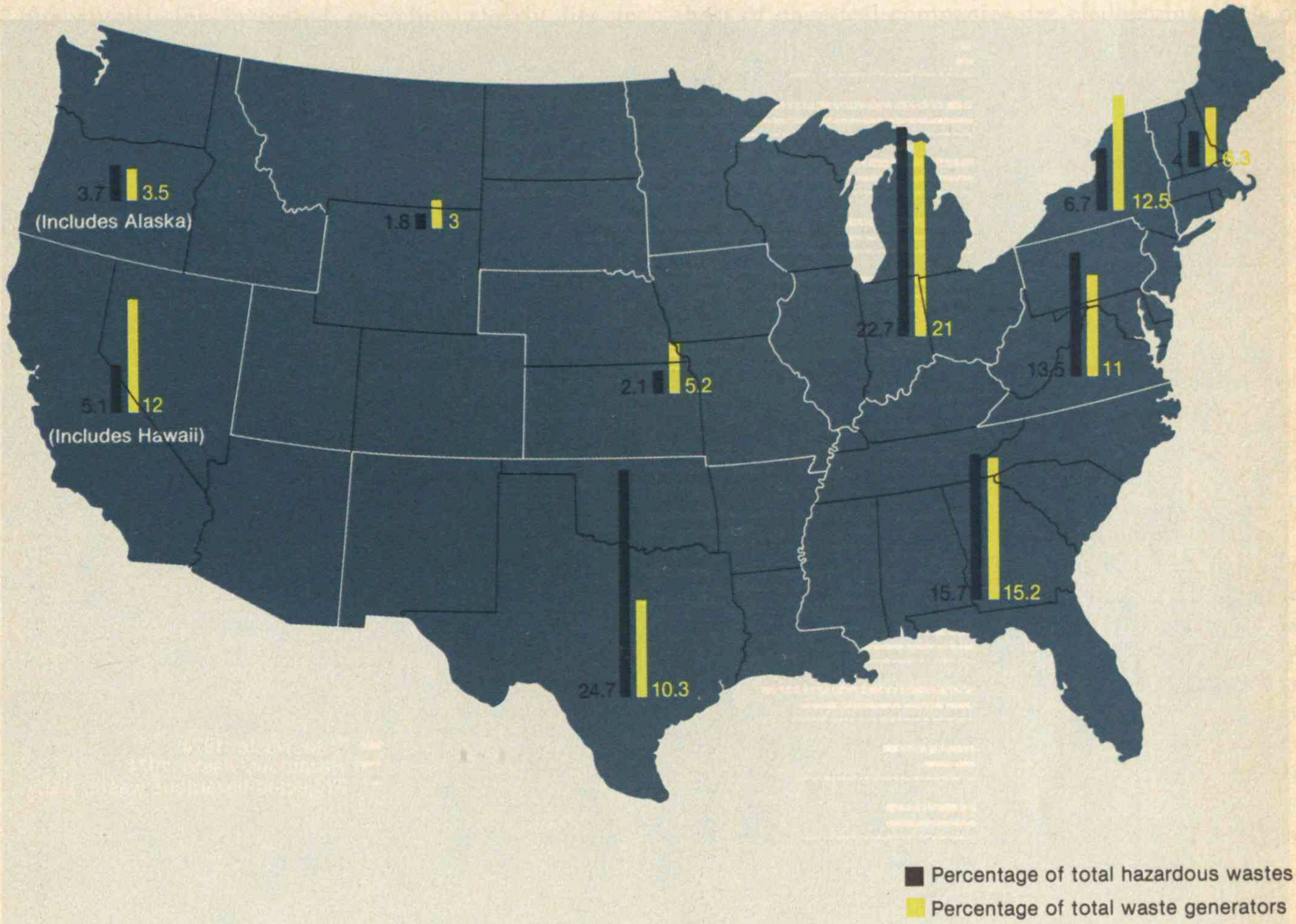
Essentially all industries, both manufacturing and nonmanufacturing, produce hazardous wastes in varying amounts and compositions. Most wastes come from very large generators, typically large manufacturing facilities located in the Mid-Atlantic, Southeast, Great Lakes, and Gulf Coast regions. In the nonmanufacturing sector, generators include schools, hospitals, gas stations, and repair garages.

In all, there are about 760,000 individual generators of hazardous wastes. About 40,000 produce more than five metric tons of wastes per month, while 695,000 produce less than one metric ton per month. The top 5 percent of the generators are reponsible for 98 percent of the nation's wastes, while 91 percent of the generators together contribute only 1 percent of the total. However, the geographical distribution of large and small generators is not uniform nationwide (*see the figure at the right*). This regional variation is one of the factors making federal regulation of hazardous wastes difficult.

The EPA has estimated the total wastes and hazardous wastes generated by 14 specific industries (*see the figure on page 38*). Primary-metals and inorganic-chemicals industries are the biggest waste producers on the list, yet proportionally the fractions of their wastes that are hazardous are extremely low: 7.5 percent and 5 percent, respectively. Excluding pharmaceuticals, the other industries produce wastes that range from 24 percent to 100 percent hazardous. Together, the primary-metal, organic-chemicals, pesticides, explosives, electroplating, and inorganic-chemicals industries produce about 83 percent of the total hazardous wastes generated by the industries.

A complete picture of the hazardous-waste problem must include wastes produced and handled in the past. It's estimated that from 330 to 570 million metric tons of hazardous wastes were produced between 1960 and 1980. Though some of these wastes have been eliminated through proper treatment and disposal, significant quantities have been kept in over 100,000 industrial disposal sites, many still operating today. In addition to the identified sites, we must assume there are many sites that have long been closed and cannot now be accounted for. Clearly, not all industrial sites pose an immediate threat to human health, but experts estimate that between 1,200 and 34,000 sites may cause problems, such as underground water contamination, and eliminating dangers at those sites may cost more than $50 billion.

Unfortunately, precise sources, volumes, and components of the nation's hazardous wastes are not yet known and may never be public knowledge: the industrial sector is highly competitive and secretive, and



In 1980, an estimated 760,000 generators produced 35 to 60 million metric tons of hazardous waste. Most wastes come from large generators—typically large manufacturing plants in the Mid-Atlantic, Southeast, Great Lakes, and Gulf Coast regions. Proper treatment and disposal of hazardous wastes from large generators will make the greatest national impact, but in many regions small hazardous-waste generators pose serious local problems.

many companies believe information on their waste streams should remain confidential. But if we consider the enormous quantities of hazardous wastes being generated and stored, the persistence of many of the constituent compounds, and the difficulties involved in identifying their short-term and long-term toxic effects, we must conclude that our hazardous-waste problem is very serious indeed.

Waste Generation and Management

Hazardous wastes are produced by virtually all types of industries, and characteristics of the waste streams are as variable as the industries themselves. Although many cleanup and disposal options exist, no single process can be applied to all types of waste streams. Considerable knowledge and judgment are needed to select a suitable process for each specific waste or class of wastes.

To clarify the approaches to managing hazardous wastes, it is helpful to consider general pathways by which wastes are generated. There are essentially three sources of wastes (*see the figure on p. 36*). All industries require raw materials, and frequently a fraction of those materials ends up as waste streams. The process of using raw materials to form a product or perform a service also produces a substantial amount of waste. Finally, consumers create wastes by using and discarding the products.

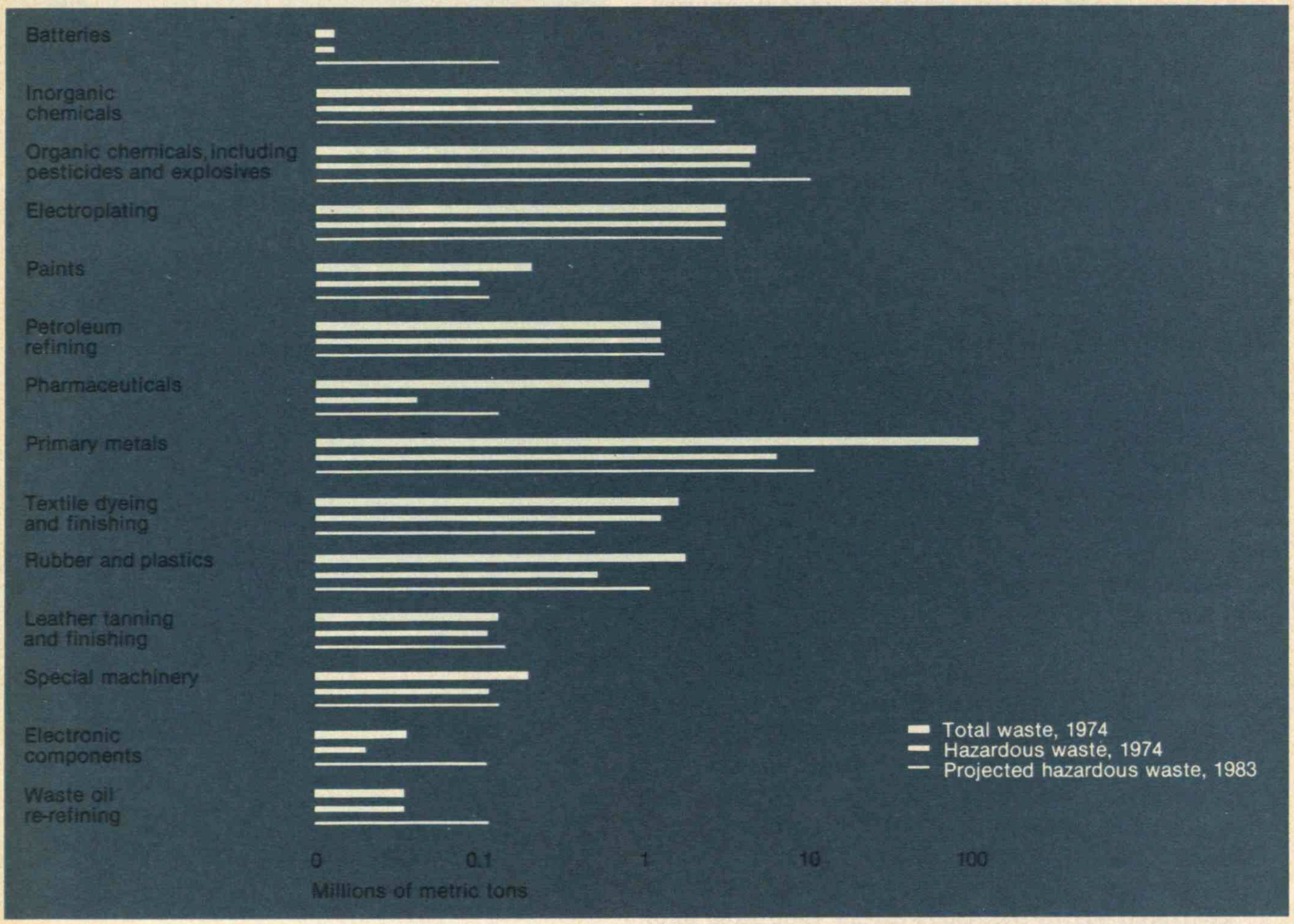
There are several options for managing wastes, also shown in the figure:

☐ They can be recycled within the industry that produced them.

☐ They can be sold to another industry.

☐ They can be treated and recycled within the same industry, sold to another industry, or disposed of.

☐ They can be disposed of without pretreatment (a practice that is illegal for hazardous wastes).



Total and hazardous wastes generated by 14 specific U.S. industries, estimated by the Environmental Protection Agency.

This analysis is valuable because it makes clear the several strategies available for reducing the hazardous-waste problem.

Source Reduction. Clearly, the ideal solution involves reducing the quantity and danger of hazardous wastes produced in the first place. Although source reduction is not always feasible, many industries are working to modify their processes to accomplish that end. Some companies are altering or pretreating their feedstocks, while others are changing processes or selected operating conditions to reduce the formation of hazardous compounds. The expenses will be partly offset by lower treatment and disposal costs and reduced potential for future problems.

Such economic incentives have recently been increased: industry must use expensive treatment and disposal practices mandated by RCRA, and must pay high prices for raw materials, particularly petroleum, petroleum-derived intermediates, and strategic minerals. Nevertheless, regulatory action may be required to ensure that all waste producers pursue source reduction. It is encouraging that industry has made significant changes, a notable example being the development of easily biodegradable pesticides to replace persistent ones such as DDT.

Waste Recycling and Reuse. Despite source reduction, however, some hazardous wastes will no doubt be produced. Before disposing of those materials, industry can explore another option: recycling and reuse. In the past, environmental regulations were minimal, and the cost of recovering materials from waste streams was greater than the cost of acquiring new materials; recycling was therefore rare. But higher costs of treatment, disposal, and raw materials are making recycling far more attractive.

Most companies are actively pursuing new ways to recover and reuse their own wastes. But given the wide variety of companies nationwide, the greatest

Clearly, the ideal solution involves reducing the quantity and danger of hazardous wastes produced in the first place.

opportunity for increased recycling clearly lies in industry-to-industry transfers. However, such transfers are difficult to arrange because of competition; industry places great value on secrecy, so it is difficult if not impossible for one company to know what materials are available from another.

This problem is being solved through establishment of waste clearinghouses and waste-exchange organizations that list available materials without identifying their sources. When RCRA was passed in 1976, there were 4 such waste exchanges; in 1981 there are at least 29. And many of today's exchangers are quite aggressive: while some still simply provide lists of available materials, others seek out both producers and potential consumers. There are also waste brokers who act as agents for waste-generating companies, receiving a commission for each successful sale.

One of the fastest-growing recycling markets is in chemical solvents. Recycling solvents has always been feasible; these high-value compounds can frequently be recovered by simple distillation techniques. RCRA further encouraged such recycling by making disposal of spent solvents difficult and expensive. By early 1981, solvent recycling involved some $200 million per year, and experts foresee a billion-dollar yearly market by 1986. The National Association of Solvent Recyclers, formed in Dayton, Ohio, in 1980, now has 43 members. These and other companies are making plans to construct improved facilities to handle chemical solvents. Some of the plants will recycle all the solvent, some will recycle part of the material and recover the rest as synthetic fuel oil, and others will convert all the waste to fuel.

While the trend toward recycling is clear, more can be done. Today only about 10 percent of the materials listed with waste exchanges actually changes hands; in older European organizations 30 to 40 percent is traded. Part of the problem stems from current regulations. Provisions of RCRA do not cover recycling activities comprehensively. For example, under present law some recyclers are not required to have permits for processing wastes unless they generate their own hazardous wastes. (However, recyclers may need permits for storage and transportation.) Such complications may make waste-generating companies hesitant to deal with recyclers and brokers, because if the company receiving the waste does not handle it correctly, the liability may revert to the waste generator.

The EPA is now considering revising RCRA to provide for better control over waste recyclers. However, the Chemical Manufacturers Association and a host of chemical companies are challenging EPA on the grounds that materials destined for recovery, recycling, and reuse are, by definition, not waste and thus should be exempt from hazardous-waste regulations. Although this point is valid, the likelihood that such an exemption will materialize is quite slim, as some recyclers were among the major offenders of environmental law in the past.

Meanwhile, two bills supporting recycling are being considered by Congress. One would make procedural changes in RCRA that encourage creation of pollution-control facilities, including recycling units. The other would increase the investment tax credit for companies involved in energy conservation and waste recycling. Senate hearings on the former bill were held in June 1981; hearings on the latter bill have yet to be scheduled. With such changes pending, the outlook for recycling is better than ever.

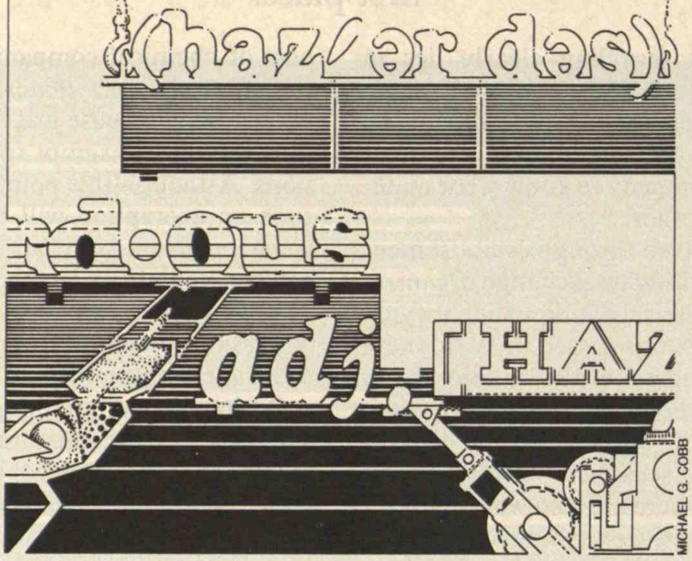
However, we must not have unrealistic expectations: according to a 1976 study by Arthur D. Little, only 3 percent of the 350 million metric tons of industrial wastes generated that year were potentially recyclable, although the fraction of hazardous wastes that is recyclable is probably higher. Changing regulations and rising prices have no doubt increased both percentages, but the fact remains that for certain types of wastes, recovery and recycling are simply not yet practical. The best we can do is to treat and dispose of such wastes in an environmentally safe way.

Classifying Hazardous Wastes

There are many waste-treatment and disposal processes, each best suited to certain types of materials. Therefore, the first step toward effective waste management is to examine an individual waste stream in enough detail to identify the appropriate processing techniques. The most practical method of classifying substances is according to their basic physical and chemical properties.

The first decision involves the state of the waste stream: is it predominantly a gas, a liquid, a solid, or a mixture? Next, the waste is classified according to its chemical constituents: are they organic or inorganic? Explosive materials should be identified, as they require special handling. Both organics and inorganics are subdivided into aqueous and nonaqueous categories, and then classified according to their concentrations of heavy metals. Heavy metals are important because their presence complicates many waste-treatment operations. Organic wastes can be further classi-

The Difficulties of Defining Hazardous Wastes



ESTABLISHING effective and just hazardous-waste regulations is difficult, in part because it is hard to define precisely which materials should be considered hazardous. Should a chemical be classified as hazardous because at some dosage it is toxic to humans? If so, should it be regulated only at certain levels of generation?

Not surprisingly, different people offer drastically different answers to such questions. At one extreme are those who believe human activities should generate no pollutants; they advocate very strict government regulations. At the other extreme are those who believe industry can and should take responsibility for protecting the public; they are opposed to any government regulation of any industry.

A Delicate Balance

The practical optimum is somewhere between those extremes, and therein lies the problem. The best regulations would protect human health and the environment while imposing the minimum economic hardship on industry and thus our national economy. Unfortunately, we do not fully understand the possible long-term adverse health effects of many chemicals. Indeed, only recently has environmental contamination been recognized as a problem worthy of intensive scientific research. Regulators have thus been faced with the problem of imposing quantitative pollutant emission controls in the presence of little (if any) solid scientific data.

Some hazardous wastes have properties that are easy to recognize—for example, ignitability, corrosivity, reactivity, and acute toxicity—making their definition and regulation relatively uncontroversial. However, chronically toxic chemicals are harder to identify and thus are the subject of considerable controversy. Chronically toxic compounds can take 15 to 20 years or longer to produce adverse health effects. Because everyone is exposed to a wide variety of chemicals for many years, it is difficult to identify cause-and-effect relationships. Although epidemiological studies, bioassays, and other research efforts provide some insight, our understanding of the scientific principles of chronic toxicology is in its infancy and inadequate for clearing up regulatory disputes.

Defining and identifying acutely toxic chemicals can also be a problem because virtually all substances become toxic at sufficiently high doses. Some chemicals produce death in microgram doses and thus are commonly considered extremely hazardous or toxic. Others are essentially harmless, inducing a toxic response only at doses over several grams. But most chemicals fall between those two extremes, posing the question of where on such a scale we make the (perhaps arbitrary) switch from "toxic" to "safe."

There is yet another problem in deciding whether specific compounds are hazardous. Laboratory tests generally focus on a single compound, but compounds almost always exist in mixtures, and there is growing evidence of synergisms between them. Thus, the health impacts of the mixture may be totally unlike those of the individual components. For example, we may determine that a compound is harmless, but in combination with another (perhaps harmless) chemical, this compound may become highly toxic. Since we do not understand how these interactions occur, we need to examine not only an enormous number of chemicals but also all possible combinations—a formidable task. Furthermore, most standard laboratory studies use nonhuman subjects and high chemical doses, so another troublesome question is how reliably we can extrapolate the results to people. Although this is also a highly controversial area, single-cell and animal tests will be the major source of quantitative toxicity data until better means are developed.

Despite the present shortage of information, in response to public outcry, the U.S. Environmental Protection Agency (EPA) developed a system for identifying hazardous wastes through well-defined characteristics such as ignitability, corrosivity, reactivity, and acute toxicity as determined through a specific extraction and testing procedure. The EPA system also considers each chemical's chronic toxicity, changes in its health impacts at various concentrations, its potential for degrading into toxic products, its persistence in nature, and its potential for bioaccumulation. The EPA has also created a list of specific and nonspecific hazardous-waste streams.

There are several indications of the difficulty EPA had in establishing hazardous-waste regulations. First is the long time delay before any action was taken. The Resource Conservation and Recovery Act mandated that EPA establish hazardous-waste regulations in 1976, but the agency did not publish any rulings until May of 1980, primarily because of its problems in defining the legal and technical terms on which the rulings are based. Even today, those terms are not defined with sufficient scientific rigor—this situation leads to continuing conflict between industry and regulatory agencies.

As the List Changes

As an even clearer demonstration of the problems of regulating hazardous wastes, the official list of hazardous wastes is constantly changing. In May 1980 that list contained about 300 chemicals and 80 waste streams (*see the figure*). There have been almost daily additions to the list as more toxicological evidence is obtained about specific compounds or groups. Not surprisingly, many substances

have also been deleted, since EPA created the list under substantial public pressure and in many cases without sound scientific data. Given that situation, the tendency was to include any waste streams that aroused the slightest suspicion. Whenever research uncovers an unnecessary item on the list, industry claims "overregulation."

Arguments among environmentalists, waste-producing industries, and regulators (who consider themselves caught in the middle) are energetic and often emotional. The difficulties of regulating hazardous wastes can be reduced only through the acquisition of better scientific data. Recognizing that fact, researchers are now creating new fields of study combining engineering, environmental chemistry, and toxicology to help define and quantify the risks associated with various types of potentially hazardous wastes. With such information we will be in a better position to attack the complex issue of determining which risks can be reduced or eliminated, and what levels of risk we may have to accept to maintain our industrialized society.—*S.M.S.* and *N.W.S.* □

Specific Waste Sources:	
Wastewater treatment sludge from production of chrome green pigments.	
Heavy ends from carbon tetrachloride production	
Heavy ends from vinyl chloride production	
Wastewater treatment sludge from production of chlordane	
Spent pickle liquor from steel finishing	
Nonspecific Waste Sources:	
Scrubber sludges from coke ovens and blast furnaces	
Bath sludges from electroplating operations	
Spent halogenated solvents (tetrachloroethylene, trichloroethylen chlorobenzene, etc.)	
Specific Compounds:	
4-Aminopyridine	Chlorobenzene
p-Chloroaniline	Chloroform
Ethylcyanide	DDT
Hexachloropropene	Methanol
Methylparathion	Naphthalene
Phosgene	Phenol
Asbestos	Formaldehyde
Benzene	Toluene

The Environmental Protection Agency has compiled a list of hazardous wastes and waste streams, considering such factors as acute and chronic toxicity, ignitability, corrosivity, breakdown products, and potential bioaccumulation. In May 1980, the list contained 300 chemicals and 80 waste streams; examples are shown in the table. There have been many additions and deletions as the list has developed, with changes often bringing charges of "overregulation" from some industries.

fied according to whether they are biological.

Unfortunately, most waste streams contain mixtures of all sorts of materials, and it is necessary to use several processes, either in series or in parallel. Since this practice leads to even higher treatment costs, it is likely that industries generating hazardous wastes will move in the direction of making their waste streams more uniform.

Designing Facilities

Choosing an optimal design for a waste-treatment and disposal facility is not simple, as different generators have different needs and options. There are at least three possible choices for generators of small quantities of hazardous wastes. They can install permanent, small-scale treatment facilities at plant sites and then use regional sites for ultimate disposal of treatment residues. They can use a contractor with specialized, mobile treatment units that operate at the plant site from time to time. Or they can use the services of a specialized treatment/disposal company.

The concept of a completely integrated regional facility is appealing but hard to implement (*see the figure on page 44*). Such a facility must be able to handle both large and small quantities of hazardous wastes at a reasonable cost, and must be readily accessible to a large number of generators. The siting of such a facility involves careful analysis of the geography, geology, topography, and hydrology of an area, along with social, economic, and political factors.

While integrated regional facilities are useful for small generators, companies that generate large quantities of wastes may be best served by having their own waste-treatment systems, even if there is no suitable landfill nearby for disposal of the treatment residues. Treating the wastes at the point of generation frequently reduces the amount and danger of the waste material and provides substantial reduction in transportation and related costs. Having their own treatment plants also enables companies to take greater advantage of recovery and recycling.

Treatment and Disposal Methods

There is a long list of processes for treating hazardous wastes (*see the table on page 43*). These processes are basically designed to reduce the volume of the waste, separate it into individual components that are easier to process, and/or detoxify it. Often certain processes also allow resources to be recovered. Each

Treatment processes are designed to reduce the volume of the waste, separate it into individual components that are easier to process, and detoxify it.

process ultimately produces residues that require a final disposal site, typically a secured landfill. Rather than describe each process, we will focus on a few that have a relatively broad range of applicability.

Incineration and Pyrolysis. The hazardous nature of certain wastes may be due to the structure of the molecules present rather than to the properties of the elements contained. In such cases, high-temperature treatment may simultaneously detoxify the waste and reduce its volume. The most common thermal treatment methods are incineration and pyrolysis.

Incineration involves burning wastes in the presence of sufficient oxygen with or without the use of an auxiliary fuel source. The products are generally gases (carbon dioxide, steam, hydrochloric acid, and sulfur dioxide) and ash with essentially no heating value. Pyrolysis essentially involves heating wastes in the absence of oxygen: the wastes thermally decompose to form a solid carbonaceous residue along with gaseous products. Often these two processes are combined.

The advantages of incineration and pyrolysis are substantial. These processes can in principle be applied to almost all organic wastes not severely contaminated by volatile heavy metals, and they can be used equally well on some inorganics. The facilities are capable of handling large volumes at a time, there is potential for energy and materials recovery, and the necessary equipment requires relatively little land. Finally, the processes can reduce the volume of most wastes to a minimum, reducing their danger and the costs of storing and transporting them.

However, there are several disadvantages to incineration and pyrolysis. The processes tend to be technically complicated and costly to operate—as high as $300 per cubic meter of waste. The methods may not be directly applicable to some hazardous-waste streams because of the unusual combustion characteristics of some toxic wastes, especially those containing halogenated compounds. In addition, under some circumstances the processes produce a toxic residue that requires special disposal techniques, and they frequently give off pollutants such as carbon monoxide, hydrochloric acid, chlorinated dioxins, sulfur dioxide, or soot, requiring strict operating controls and additional pollution-control equipment.

Incinerators are used both at industrial plants where wastes are generated and at specialized disposal facilities. Incineration requires the user to select a system design suited to the type of waste, and operating conditions should be fine-tuned to the particular waste being burned. Certain materials in wastes also require special handling. For instance, heavy metals such as arsenic, selenium, sodium, and mercury must be removed before incineration.

Our understanding of the subtleties of incineration and pyrolysis is limited, but advances are being made. For example, the Midwest Research Institute in Kansas City is opening a facility that will provide information on the compounds formed in an incinerator. The facility simulates actual incinerator conditions, but includes ports from which samples can be taken; the compounds in those samples can be identified and quantified. By running the system under different operating conditions, the researchers claim they can identify conditions that result in 99.99 percent destruction of the principal organic hazardous constituents—the level required by EPA.

In our laboratories in the Department of Chemical Engineering and the Energy Laboratory at M.I.T., fundamental combustion studies are in progress. We are examining the basic combustion characteristics of a variety of chlorinated hydrocarbons and their mixtures, thereby establishing a better understanding of the scientific principles involved in the incineration of toxic chemical wastes. And at the University of Dayton, researchers are examining the pyrolysis characteristics of toxic chemicals using a laboratory-scale thermal-decomposition analytical system.

Biological Methods. Biological treatment offers an effective means of handling organic and some inorganic toxic wastes. The waste stream is brought into contact with microorganisms that detoxify the waste material—decomposing organic molecules into carbon dioxide, water, or compounds with lower molecular weights. If the microorganisms are aerobes, molecular oxygen must be added to the systems; if they are anaerobes, oxygen is not necessary for them to degrade the wastes. (There are also certain microorganisms that can act either as aerobes or as anaerobes.) Of the aerobic and anaerobic processes, the former are generally faster and have wider applicability.

Principal biological treatment processes include activated sludge systems, trickling filters, aerated lagoons, anaerobic digestion systems, and composters. The first three processes can be used for aqueous waste streams with total contaminant levels under 1 percent. The activated sludge system is particularly well-developed and tested, having been used in industry for many years. Its attractive features include compactness, flexibility, and relatively rapid rates of degradation.

Major hazardous-waste treatment and disposal processes

Process	Function Performed	Type of Waste	Forms of Waste	Typical cost range (Dollars per cubic meter of waste)
Physical treatments:				
Sorption	VR,Se	1,3,4,5,6	L,G	5 - 20
Dialysis	VR,Se	1,2,3,4	L	—
Electrodialysis	VR,Se	1,2,3,4,6	L	5 - 10
Evaporation	VR,Se	1,2,5	L	2 - 5
Filtration	VR,Se	1,2,3,4,5	L,G	5 - 10
Flocculation/settling	VR,Se	1,2,3,4,5	L	1 - 5
Reverse osmosis	VR,Se	1,2,4,6	L	—
Stripping	VR,Se	1,2,3,4	L	10 - 50
Freezing/freeze drying	VR,Se,St	1,2,3,4,6	L,G	5 - 20
Distillation	VR,Se	1,2,3,4	L	25 - 100
Extraction	VR,Se	1,2,3,4	L,S	5 - 25
Magnetic separation	VR,Se	1,2	S,L/S	—
Chemical treatments:				
Ion exchange	VR,Se,De	1,2,3,4,5	L	5 - 10
Neutralization	De	1,2,3,4	L,G	2 - 10
Oxidation	De	1,2,3,4	L	50 - 150
Precipitation	VR,Se	1,2,3,4,5	L	1 - 10
Reduction	De	1,2	L	50 - 150
Incineration/pyrolysis	VR,De,Di	1,3,5,6,7,8	S,L,G	30 - 300
Catalysis	De	1,3,7,8	L,G	—
Plasma treatment	De	1,3,6	S	50 - 300
Biological treatments:				
Activated sludges	De	3	L	2 - 10
Aerated lagoons	De	3	L	1 - 5
Waste stabilization ponds	De	3	L	—
Trickling filters	De	3	L	—
Composting	De	3,4	L,S	3 - 20
Enzyme treatment	De	3	L	—
Disposal/storage:				
Deep-well injection	Di	1,2,3,4,6,7	L	1 - 5
Engineered storage	St	1,2,3,4,5,6,7,8	S,L,G	100 - 300
Land burial	Di	1,2,3,4,5,6,7,8	S,L	5 - 10
Ocean disposal	Di	1,2,3,4,7,8	S,L,G	2 - 5
Solidification/encapsulation	Se,Di	1,2,3,4,5,6,7,8	S,L,G	10 - 100

VR = volume reduction
Se = separation
De = detoxification
Di = disposal
St = storage

1 = inorganic chemical without heavy metals
2 = inorganic chemical with heavy metals
3 = organic chemical without heavy metals
4 = organic chemical with heavy metals
5 = radiological
6 = biological
7 = flammable
8 = explosive

S = solid
L = liquid
G = gas

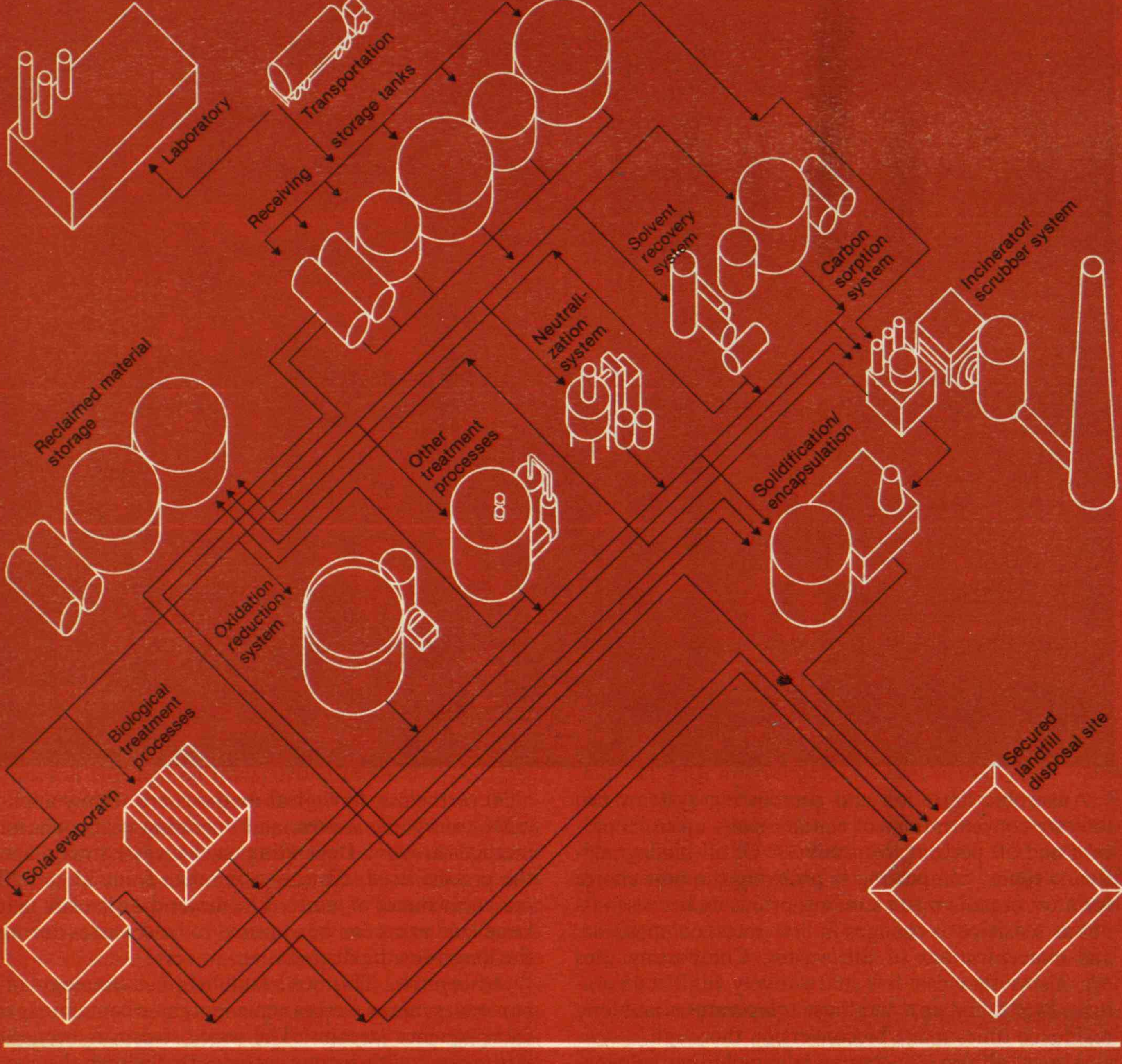
Anaerobic digestion and composting systems can tolerate concentrations of contaminants up to 10 percent and 50 percent, respectively. Of all biodegradation systems, composting is probably the best choice for most organic waste streams, primarily because it is not as sensitive to changes in flow rates, composition, and concentrations of the wastes. Composting uses organisms that can live at relatively high temperatures (45°C and up), and those temperatures and long residence times make bioconversion thorough.

Almost all organic compounds, including halogenated hydrocarbons, are biodegradable. However, there are a few limitations. The compounds in the waste must be nontoxic to the microorganisms. The wastes also must contain some water: enzymes play a key role in the microorganisms' degradation of wastes, and enzymes require water for their activity. Soluble inorganics must be kept to a minimum as they can inhibit the enzymatic conversion process and are generally unaffected by biological treatment.

Nevertheless, biological methods are widely applicable to organic wastes, and operating costs of most methods are low. Depending on the waste stream and the process used, typical costs range from $1 to $20 per cubic meter of waste. The major drawback is that large land areas can be required to hold wastes during the long, slow biodegradation process.

Adsorption. This well-established technology removes organic as well as some inorganic contaminants from aqueous streams. The waste stream is brought into contact with porous particles that adsorb the contaminants; the contaminant-bearing particles are then removed from the system. The adsorption process is often reversible, so removed material can be recovered or treated for disposal, and the sorbent can be regenerated and recycled. The costs of such treatment are generally between $5 and $20 per cubic meter of waste treated.

The most common sorbent is carbon. Activated carbon has been used for years to treat drinking and

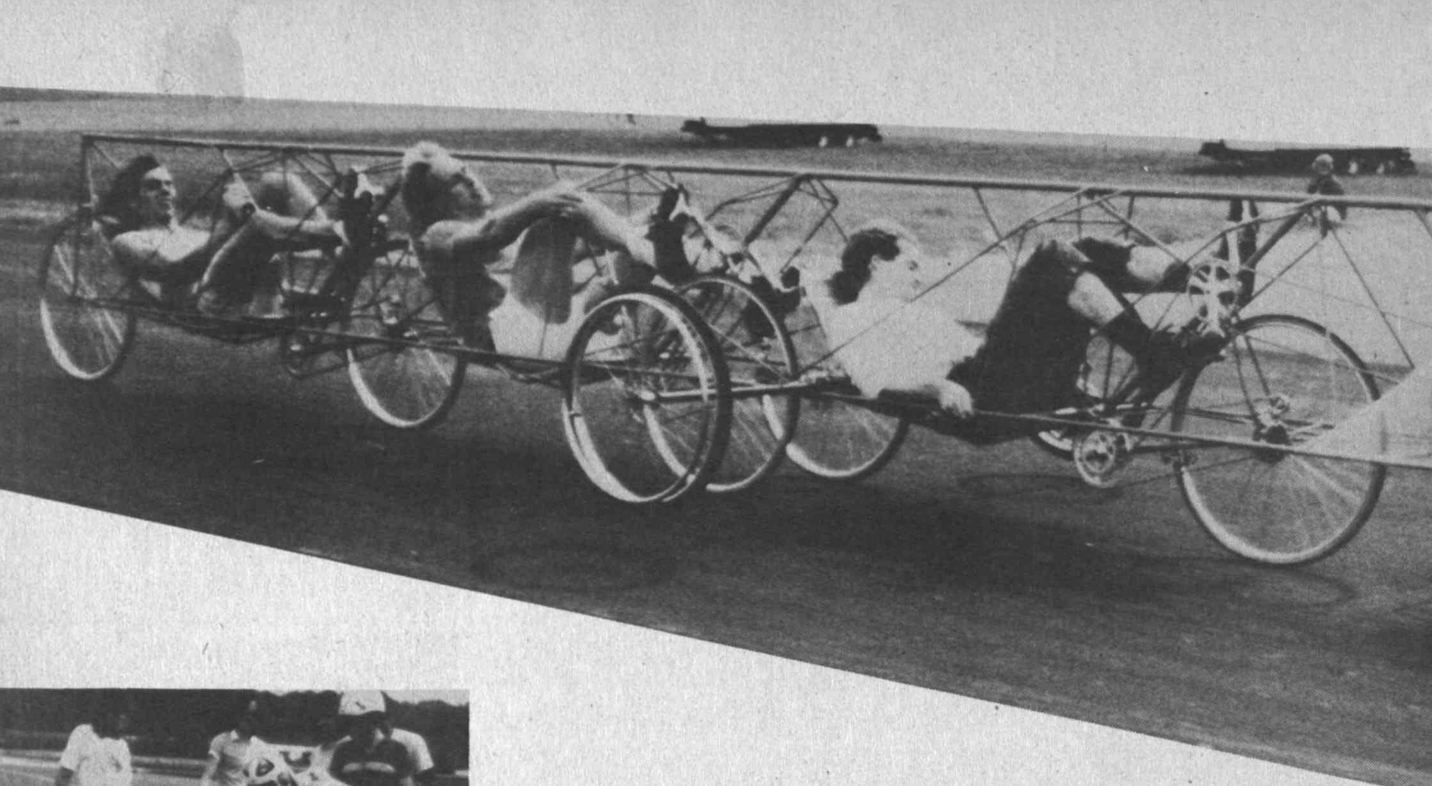


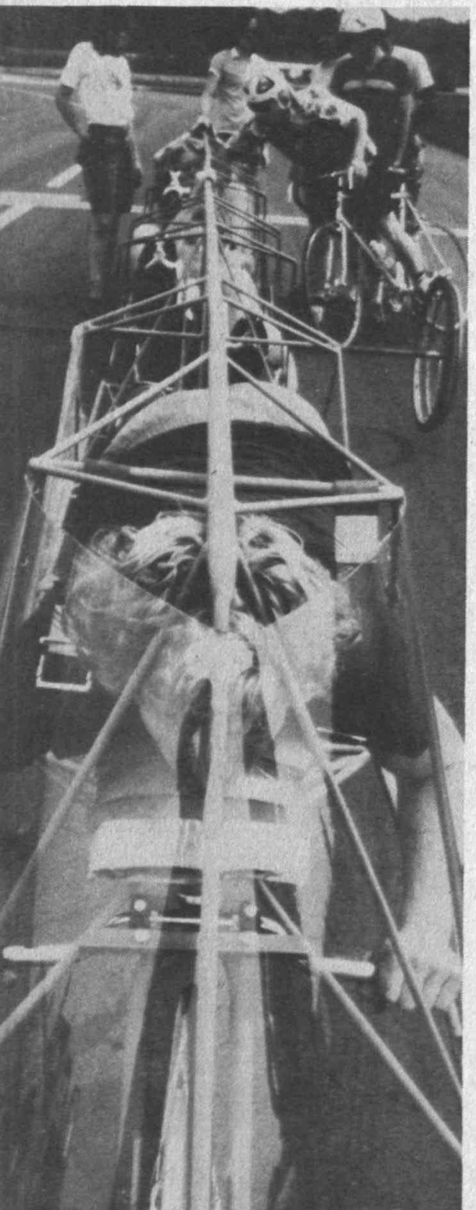
An integrated hazardous-waste treatment and disposal facility, here represented schematically, must be able to handle both large and small quantities of hazardous waste at a reasonable cost and be accessible to many generators.

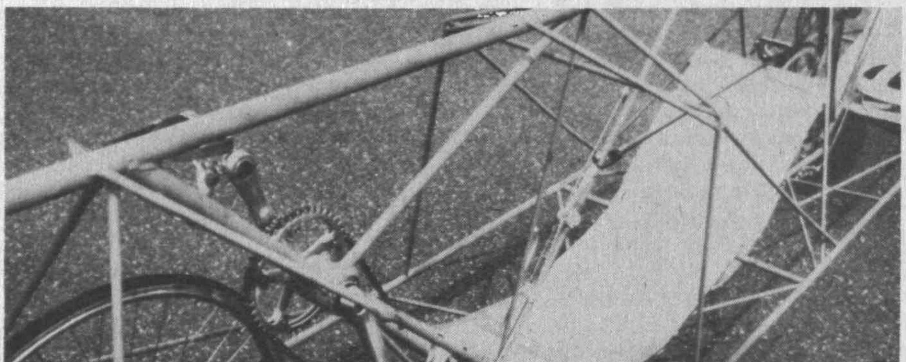
Individual treatment processes may differ from facility to facility, but two components are essential to any such operation. First, there must be a well-equipped laboratory, perhaps the most important part of an integrated facility, since here incoming hazardous wastes are examined and treatment methods selected. The laboratory oversees the operation of each system in the facility. To minimize operating costs and risks associated with handling the wastes and storing the residues, every treatment operation must function with utmost efficiency. Monitoring the secured landfill leachate and streams from the various processes requires a dedicated laboratory and personnel equipped with the necessary analytical tools.

Second, there must be sufficient storage space, primarily because incompatible waste streams must often be stored in isolation. Separate storage is also useful because one waste stream can sometimes be used to treat another. For example, acids and bases can be combined to neutralize each other.

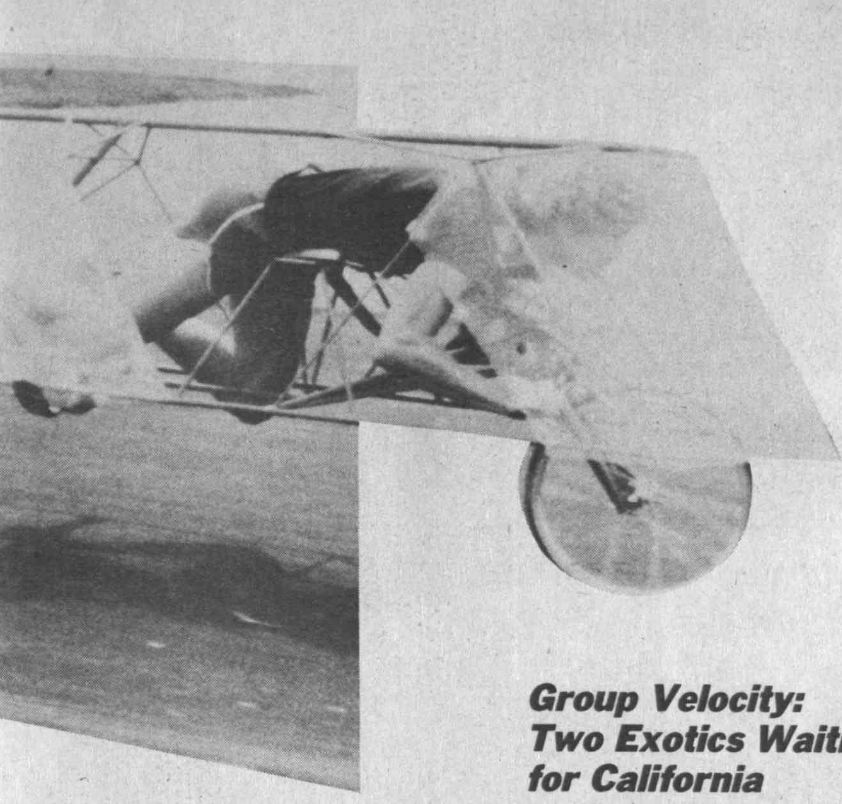

Four Men on a
Bicycle at 35 mph
AOC: M.I.T.'s Past
and Future Strength
How to Be at Ease
in Admissions
MIT

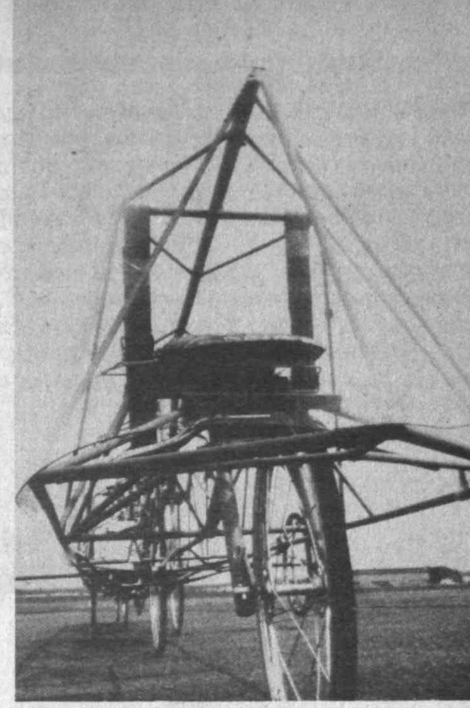






Without a proper fairing and in only a few hundred yards of distance, the four-man world-record contender built last summer by M.I.T.'s Group Velocity, now renamed the Human Power Vehicle Association, reached more than 35 miles an hour, still accelerating. The outboard wheels at the middle were to prevent the 42-foot-long machine from tipping, but they proved never to touch the ground during actual runs. Each driver's crankset (above) is activated by foot-power; hand-cranks will be added later. So will a streamlined shell, to replace the Lexan sheet which shows in these early photographs. Then it will be on to California for the world championships next May. (Photos: Leonard A. Phillips)





Group Velocity: Two Exotics Waiting for California

From Brighton, England, comes good news and bad news for aficionados of speedy human-powered vehicles. The good: American entries handily won both the sprint contest on September 5 and the following 15-lap road race (not, however, setting new records). The bad: M.I.T.'s Group Velocity couldn't compete because they failed to raise the needed air fare.

Now the team is gearing up for the next such race, also sanctioned by the International Human-Powered Vehicle Association, which will be held in California early next May. Howard J. Rosenberg, graduate student in nuclear engineering, and Bruno Mombrinie, '82, in mechanical engineering, major forces in the group, agree that there should be "no problem" in transporting their entries to the West Coast for that event (trucking comes naturally to this crew, if not flying).

The consensus of Rosenberg and Mombrinie doesn't, however, extend to vehicle design parameters.

Early in June the two students crystallized very different approaches, leading to the formation of two contingents within Group Velocity—and two vehicles. During the remaining weeks of July (and the first days of August), two of what must be the world's longest human-powered streamliners, both over 40 feet long, slowly took shape in workshops located at opposite ends of the basement under the main buildings.

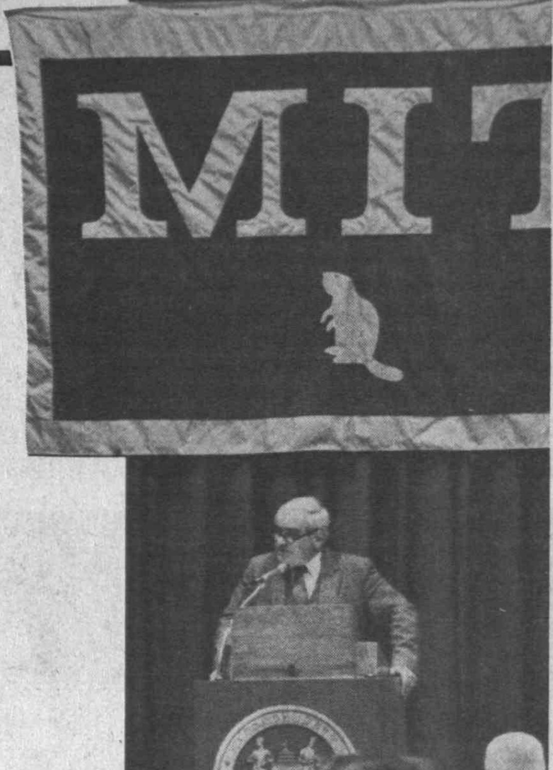
The construction efforts were Herculean. Cutting, mitering, and brazing of tubing, fitting of brakes and drivetrains, designing and fabricating of seats went on at all hours of the night in a push to finish building in time to test the vehicles and hopefully compete in September.

During strings of "all-nighters" the pungent aromas of late-night pizzas, submarine sandwiches, and an occasional beer mingled with machine oil and sweat. Impromptu suppers were served with gusto among drill presses, drafting tables, tanks of oxygen and acetylene, lathes, and boxes of parts. Fatigue was forgotten as the students' formidable energies, released from the burden of academic challenges, were focused with combatants' resolve on structures of brazed tubing that grew daily more complex yet more recognizable as vehicles. Here, a brazing torch hissed the genesis of a new tubing junction; there, team members clustered around a hastily penciled sketch showing the highlights of the next stage of construction.

Mr. Rosenberg's group settled finally on a four-rider crew; Mombrinie's on five riders. The drivetrains and steering mechanisms also contrasted: a system of chains, conventional bicycle sprockets, and derailleurs and a single steering wheel on the Rosenberg vehicle; a unique, shiftless spool system (they called it their "whisper transmission") good for a one-way trip down the track (whereupon it must be rewound for the next run) and a two-wheel steering mechanism in the Mombrinie.

In mid-August both vehicles completed short test runs at the M.I.T. Lincoln Laboratory Flight Facility at Hanscom Field in Bedford. And both had their share of gremlins and glitches—for example, thrown chains (traced to loose crankset bolts) on the Rosenberg machine and a bent frame on Mombrinie's (which had been aligned with a laser during an all-night marathon earlier in August) due to insufficient chassis strength—since corrected with additional brazing tubes. The former machine attained speeds in excess of 35 miles per hour (according to the oscillatory speedometer needle in the aged pace pickup truck), which were approached by the latter when it deformed.

And after such a superb effort, to be so disappointed . . . the morale of a lesser group would have been squashed. But not these men and women. While the cooler weather of autumn has reordered priorities once again, the indefatigable Group Velocity, to a member, is looking forward to the spring thaw when they will surely penetrate their 62.92 mile-per-hour barrier. — *L.A.P.*



The fellowship that is traditional among alumni was mixed with the serious business of the Alumni Association at the 1981 Alumni Officers' Conference on September 25 and 26. Paul E. Gray, '54, president of M.I.T., told the alumni (this page) that each received, as a student, a "hidden scholarship" from the Institute's gifts and endowments, and now it's time "to replenish the fund which was so important to the educations we received." As chairman of the Alumni Activities Board, H. DuBose Montgomery, Jr., '71, led a three-hour discussion (far right) of club programs, concentrating on programs for continuing education.

AOC: Strengthening an Interdependence With a Positive Exponential for M.I.T.

M.I.T. is strong because its alumni have been strong and have shared their strength with their alma mater. And the alumni are strong because M.I.T. has been strong.

More than 600 alumni, called to Cambridge on September 25 and 26 to help strengthen this interdependence, learned that the symbiosis may now be more cherished and may soon be more vital than ever before.

Anticipating pressures from the national economy as well as from explicit federal policies during the next four years, President Paul E. Gray, '54, called on alumni at the 1981 Alumni Officers' Conference to "redouble our efforts to make the case for research and education in the service of the national interest." And Joe F. Moore, '52, chairman of the Alumni Fund Board, urged alumni leaders to encompass fund-raising in their basic concept of service to *alma mater*; "a mature and vital responsibility" for financial support is an essential part of alumni leadership, he said.

Replenishing the Repository

In his keynote address, Dr. Gray reminded his audience that every alumnus received as a student a "hidden scholarship" from the Institute's funds which equalled whatever that student paid in tuition. "If the Institute is to retain its quality and vitality in the future—if it is to be true to his historic purpose and if it is to rise to the great opportunities which are presented to it now—all of us who have benefitted from the time we spent here must consider 'putting back,' for future generations of students, the hidden scholarships which we ourselves received.

"All of us have, I believe, the opportunity, over our working careers, to replenish the fund which was so important to the educations we received. If we fail to do so," warned Dr. Gray, "the strength of this special place must inevitably be diminished."

Dr. Gray's warning did not come from a position of weakness. "M.I.T. is in very good health," Professor Francis E. Low, provost, told Alumni Fund leaders—"full of ideas for the future, busy with exciting and important programs." Professor Low reported that faculty salaries, on average, were up 13 percent in 1981-82 over the previous year—the first time in five years that salary increases were higher than the rate of inflation. President Gray told the alumni that undergraduate and graduate applications for 1981-82 were at "all-time highs"; that they came from students and would-be students of "startlingly" high quality; and "the mood of the student community is sound."

The first of four bronze beavers—highest award of the Alumni Association for service to alma mater—goes to Theodore T. Miller, '22, from Angus N. MacDonald, '46, president of the association. Waiting their turns are (left to right) E. Kirkbride Miller, Jr., '41, Mary Frances Wagley, '47, and Michael M. Koerner, '49. (Photo: Calvin Campbell)





Strong, too, Dr. Gray said, are the intellectual activities of the faculty and staff, assuring "the vitality and the ferment of the campus and our stature in the world of scholarship and research."

Traditions of Service

For 1980-81, at least, the Institute's financial report is also positive—a small surplus after adding significant amounts of four bequests to endowment and purchasing three buildings for academic uses. In part, Dr. Gray said, this favorable financial report is made possible by an "extraordinary" $47.5 million in gifts, the largest one-year total in M.I.T. history.

The symbiosis between M.I.T. and its alumni has clearly been a powerful force in these achievements. In financial terms, it's expressed in new records by the 1981 Alumni Fund in every index of performance: total contributions (over $7 million), total participation (over 24,000 alumni), total number of gifts exceeding $100 (over 5,700), total number of first-time gifts by recent graduates (over 800 in the classes since 1974), and total alumni giving (nearly $21 million)—figures reported by Mr. Moore on behalf of members of the Alumni Fund Board.

In personal terms, the symbiosis of alumni and M.I.T. is expressed in the work of countless graduates supporting Educational Council, club, class, and fund-raising activities. "In your loyalty, your dedication, and your ongoing concern for the well being of M.I.T.," Dr. Gray said, "you—the key leaders among the Institute's alumni—represent a great strength of this place—fulfilling every tradition of service and support by the sons and daughters of the Institute.

There were awards to recognize notable achievements:

☐ Bronze beavers, the highest honors, to Michael M. Koerner, '49 ("our key alumnus in Ontario and Eastern Canada"); E. Kirkbride Miller, Jr., '41 ("the highest standards for service and leadership on [which] we can always depend"), Theodore T. Miller, '22 ("his record of unselfish leadership for three and a half decades stands as an example . . ."), and Mary Frances Wagley, '47 ("we value the ideals and wisdom that she has shared with M.I.T. and its alumni").

☐ Presidential Citations to three alumni groups for special services: to the alumni of the state of Florida for the "extraordinary volunteer effort" leading to the third M.I.T. Florida Festival in February 1981; to the Executive Committee of the M.I.T. Enterprise Forum, a "major focus for those with interests in high-technology ventures"; and the M.I.T. Club of Hong Kong for vital programs in support of the Institute's interests in the Far East.

☐ Harold E. Lobdell ('17) Awards for outstanding service to Bill C. Booziotis, '60, John M. Davis, '67, Whitworth Ferguson, '22, Eli A. Grossman, '36, Rutherford Harris, '37, Charles E. Kolb, Jr., '67, Louis F. Kreek, Jr., '48, Paul Rudovsky, '66, Anthony R. Savina, '30, and Florence and Walter J. Smith, '28.

☐ George B. Morgan ('20) Awards for service as Educational Council members to H. Bruce Fabens, '44 (Cleveland), Walter Godchaux, Jr., '35 (New Orleans), David Gushee, '50 (Washington, D.C.), Frederick J. Kolb, Jr., '38 (Rochester, N.Y.), William E. Moss, '52

AOC: Your Choice of Two in 1982

The 1982 Alumni Officers' Conference will be different—held in two locations to encourage participation by those who cannot easily travel to the usual Cambridge location:

☐ San Francisco, September 24-25 (headquarters at the Hyatt on Union Square).

☐ Philadelphia, October 8-9 (headquarters at the Bellevue-Stratford Hotel).

Programs at both locations will be similar, and alumni officers are encouraged to plan to attend whichever meeting will be most convenient.

After a detailed review of Alumni Association affairs during the morning of September 26 (far right), alumni attending the Alumni Officers Conference turned to reports of current M.I.T. work in biology and bioengineering, ending the day with a tour (left) of the new building nearing completion for the Whitaker College of Health Sciences, Technology, and Management.

(Atlanta, Ga.), and Irvine E. Ross, '30 (Fort Wayne, Ind.)

Strengthening the Symbiosis

Though all the news is good for last year and this, the future may hold more sombre reports. Hence the emphasis, which seemed to permeate the 1981 Alumni Officers' Conference, on the opportunities and responsibilities of alumni leaders to themselves support M.I.T. and to foster support by all other alumni—and of the Institute in turn to strengthen its own.

Most alumni who heard Frank E. Perkins, '55, associate provost, were startled by the range which he described of efforts now made by the Institute to spread its technical expertise to nonstudent—including notably alumni—audiences: special summer programs, term-time professional conferences, alumni regional conferences, industrial liaison symposia, and uncounted seminars and lectures. Professor Perkins so stimulated the workshop on alumni relations at which he appeared that its discussion continued under the leadership of H. DuBose Montgomery, Jr., '71, chairman of the Alumni Activities Board, for another two hours—perhaps the most extended consideration of issues in "con-

Technology in Medicine: Four Cases of Leadership

For an example of how—in President Paul E. Gray's words—M.I.T.'s intellectual capabilities "are extraordinarily well matched to the needs of the nation," alumni attending the 1981 Alumni Officers' Conference were referred on September 26 to four fields of work applying technology to medical problems. This is an arena in which the Institute is already very strong. But its strength will be multiplied by completion of the new building for the Whitaker College of Health Science, Technology, and Management early next year, said Professor Ernest G. Cravalho, associate director of Whitaker College.

Four examples:

☐ Professor Robert W. Mann, '50, has two different visions for the work of the Newman Laboratory for Health Mechanics and Rehabilitation which he directs: a new field of computer-aided surgery and new ways to replace functional systems for people who have suffered deprivation.

Every human is different from every other in details of skeleton and muscle, but today's surgical procedures are conducted with little reference to these individual characteristics. Computer-aided surgery will be possible when a data bank on a patient's musculature is complete enough to permit an orthopedic surgeon to plan in advance the optimum solution to a surgical problem.

This vision is the ultimate application of work in the Newman Laboratory in which Professor Mann and his students are studying how muscles and nervous system together dictate the characteristics of an individual human's mobility systems. Already this work—in collaboration with computer scientists, psychologists, and brain scientists—had led to several schemes for linking human prosthetic devices with the nervous system which controlled the limbs they replace.

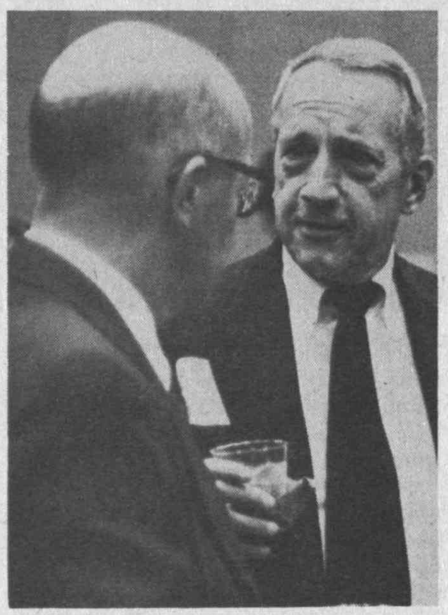
☐ Clark K. Colton, Ph.D.'69, Bayer Professor of Chemical Engineering, called attention to successful and likely future applications of technology in artificial organs. Hemodialysis units serving as artificial kidneys now comprise a billion-dollar market worldwide. The next frontier is the application of artificial hearts, a variety of which have been designed.

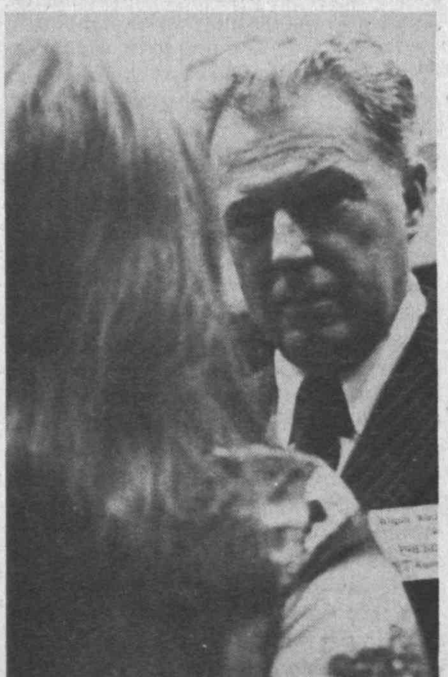
An artificial pancreas to aid diabetics is also on the horizon. Dr. Colton and his colleagues are following one trail: the development of semipermeable hollow fibers on the surface of which can be grown cells that produce insulin. Blood passing through the fibers could pick up insulin from the cells along the way.

☐ Professor Philip A. Sharp, whose work is in the Center for Cancer Research and the Biology Department, foresees a second approach to controlling diabetes, growing out of recombinant DNA technology: within the next five years, he said, it may be possible to insert functioning genes for insulin production into diabetics lacking such genes.

Dr. Sharp emphasized that recombinant DNA technology, like other technologies, rests on advances in basic science; in this case, he said, many of these have been made at M.I.T.—notably by Nobel Laureate Professors Har Gobind Khorana and David Baltimore.

☐ Christopher Walsh, Uncas and Helen Whitaker Professor who is associate director of the Whitaker College, outlined new strategies for the rational design of drugs. Consider, for example, methotrexate, widely used for cancer chemotherapy. Like most such drugs, methotrexate kills normal as well as cancer cells. The drug works by binding itself to a particular enzyme, whose role in the body is then modified. It is Professor Walsh's hope that the methotrexate molecule can be redesigned to be more selective between healthy and cancer cells, thus minimizing the drug's adverse side effects.





tinuing education" by an alumni group in the past decade.

But most of the emphasis during the Alumni Officers' Conference seemed to be on the other side of the equation—the need for alumni to provide ever-growing support, financial and otherwise, for M.I.T. For example, Bonny S. Kellerman, director of the Educational Council, hopes to increase the corps of educational counsellors so that more effort can be given to reaching minority candidates for admission and Ronald S. Stone, '59, director of operations, has targeted several regions for special attention to upgrade programs.

At the other end of the admissions process, Leonard V. Gallagher, '54, director of student financial aid, warned of possible cuts in federal student aid programs. These prospects, coupled with continued high rates of inflation (and therefore continued tuition increases), seem to Mr. Gallagher a critical problem. "We need you now, more than ever," Mr. Gallagher told the alumni, "to reaffirm the private sector's historic commitment to M.I.T. and its financial aid program."

Even the current year holds some financial uncertainty, most of it emanating from Washington and most of it—just two days after President Ronald Reagan's renewed attack on the 1982 federal budget—no more than speculation. But already it's clear, said President Gray, that "substantial reductions" will be necessary in recurring M.I.T. expenses in the budget for 1982-83. And this does not really begin to address the tough question of faculty salaries, which (except in 1981-82) "have failed to keep pace at a time when industrial demand for highly-skilled people is very strong."

At the same time, the Institute faces a continuing, threatening problem in the an acute shortage of housing for graduate students (undergraduate housing problems have been substantially relieved by completion of 500 Memorial Drive, *see page A19.*) And the fraternity system may need as much as $5.6 million in loans from the Independent Residence Development Fund during the next five years for refurbishing and relocations, Shirley M. McBay, dean for student affairs, told Alumni Fund workers.

Fund-Raising as an Explicit Obligation

No wonder, then, that Professor Robert W. Mann, '50, speaking from his vantage point as a member of the Institute's faculty and from his experience as a member of both the Board of Directors and Alumni Fund Board, proposed dual responsibilities for alumni officers and the activities they direct: provide alumni with "a sense of participation in this place and of the needs for funds." The latter, he said, is an issue that "has to be addressed directly and continuously."

The same theme was repeated at a session for club officers: there is no need to be apologetic about including fund-raising among the explicit goals of most alumni activities. To do less is to shirk the single most important responsiblity of alumni toward their alma mater, said several speakers.

Is it worth it?

Yes, said Dr. Gray. "We have, both as an institution and as individuals, much to contribute to a world in which science and engineering are powerful forces in shaping the future—a world in which informed citizenship demands both an understanding of scientific issues and a solid grounding in the humanistic disciplines.

"We have, in this special place, both the capacity and the commitment to nurture fully-educated citizens of the world."

Peter H. Richardson, '48, Director of Admissions: on Students

Photos: James J. Snyder, '81

The fear was palpable as I imagined myself a potential freshman. I sat in the formal, curtained, sunny waiting area of the M.I.T. Admissions Office waiting to talk to the director, Peter Richardson, '48. He appeared just then, motioning me into his office for an interview.

His warmth was barely enough to calm the nervousness I had by then generated. And when I expressed my fantasy, he immediately jumped into the scene: "You be a freshman, then, and I'll usher you into my office."

Where to sit? I thought, panicking.

The office was plush, lovely. Windows dominated the entire right wall, allowing stately trees and grass in Killian Court to nudge into the room, permeating it with a sense of peace. The couch was the obvious place but in my haste and discomfort I dove for a hard chair in the corner.

"What if I sit here?" I asked.

"Then I sit on the couch—never behind the large imposing desk," he said. "Usually, I would encourage you to sit on the couch. Then I sit in a chair facing you, so that behind me you see the view out the window. If your body language is radiating discomfort, I would suggest that you sit back and relax."

So I accepted that choice seat, trees as backdrop to Peter Richardson, as he shared his insights and experiences.

Contact Available Support Systems

"Who does well here?" I asked.

"Lots of different kinds of students—but all who do well have the basic academic potential when they come, fueled by self-motivation.

"Students who *don't* do well are those who don't learn quickly how to make contact with freshmen advisors and the network of people and services that help students when they find it difficult to cope. Those who get paralyzed by being away from home lower their probability of success.

"The first sign of trouble is when a student stops going to class and stops talking to his or her advisor.

"It's hard to know who's who when you're looking at their applications in March. Two students may seem similar on paper, yet their reactions to a new and different environment may be opposite.

"I remember, as an advisor, a very upset freshman who came in. 'I'm going to fail 8.01,' she said. 'No you won't if you do the work during the next couple of weeks before the final,' I said. She disappeared. I began to worry that I hadn't seen her for three or four weeks. But she burst into the office soon after that. 'Guess what I got on the 8.01 final!' It was obvious. 'What did you get?' I said. 'An A!' As an advisor I told her the obvious: to deal with the issue, and she heard me and it paid off. The important point is that somehow she was able to come to the office, so she was able to hear me say the right three or four words.

"'I can't do it, I'm so dumb. The kids are so bright,' said another student. She had a shaky term, but she's a junior now. I didn't do anything—I was here, and she knew where to find me. And M.I.T. is full of faculty and staff at all levels that will be there when needed."

"I work hard at trying to be visible on campus," he added. "As a freshman advisor, as director of the Outing Club, I maintain contact with a variety of students. It's important professionally and a real joy personally."

Changing Environment

"Is M.I.T. concerned about a dwindling college-age population?" I asked.

"To say M.I.T. is not affected by a shrinking student population is naive. The very nature of the environment is changing because everyone's been told it will change. From a selection point of view to a recruiting point of view, M.I.T. is not affected the same way a small liberal arts college is, but we are affected. As the market gets tighter, people will be increasingly willing to do things they wouldn't before. For example, they'll use scholarships to lure good students, whether the students need

financial help or not. Or they'll say, 'If you sign up *now*, we'll promise you a place, but we can't promise if you don't'—all the used car sales techniques.

"The problem is we're dealing with adolescents who lack the sophistication to know how to deal with this. Over the last 30 or 40 years it has been thought that one of the most important decisions to make is where you go to college. We tell them that. So the college process has a lot of anxiety attached to it. Now we're building in anxiety on the part of the admissions office.

"Because of the environment we must set high standards of ethics—we must keep students' best interests as the primary concern and at the same time, meet institutional needs and goals.

"I think M.I.T. will have 4,500 undergraduates for as long as we want them, and the 4,500 will be among the best in the country. But we have to be careful to assure ourselves of that in the coming decade, and to do it in a way we'll all be proud of. As the competition becomes tougher we will need additional resources, time and energy. That is to say the challenge of being in admissions will change—the needs will change; and we feel them changing now.

"If we can be successful in the next five years, in changing the perceptions of high school counselors and students of the appropriate roles for women, we can create a new pool of students. Success in that area would help us counteract the shrinking population of students. So we have practical reasons as well as philosophical ones for cultivating women."

Potential for Awareness and Commitment

"It was envisioned by Howard Johnson and Jerry Wiesner that M.I.T. be not only first in science and engineering but first in addressing the responsibilities of science and engineering to society. The thing which has made M.I.T. an exciting place to work for me is the attitude of the top administration that producing new knowledge or a new device is not enough; that the *impact* of that device on society would be addressed here.

"As long as we're committed to that, then we have to look for students with the potential to have that awareness and commitment. They don't have to have it when they get here, but they have to have the potential to have it. As the students get more focused on their prospects, it gets harder and harder to stimulate that commitment and awareness."

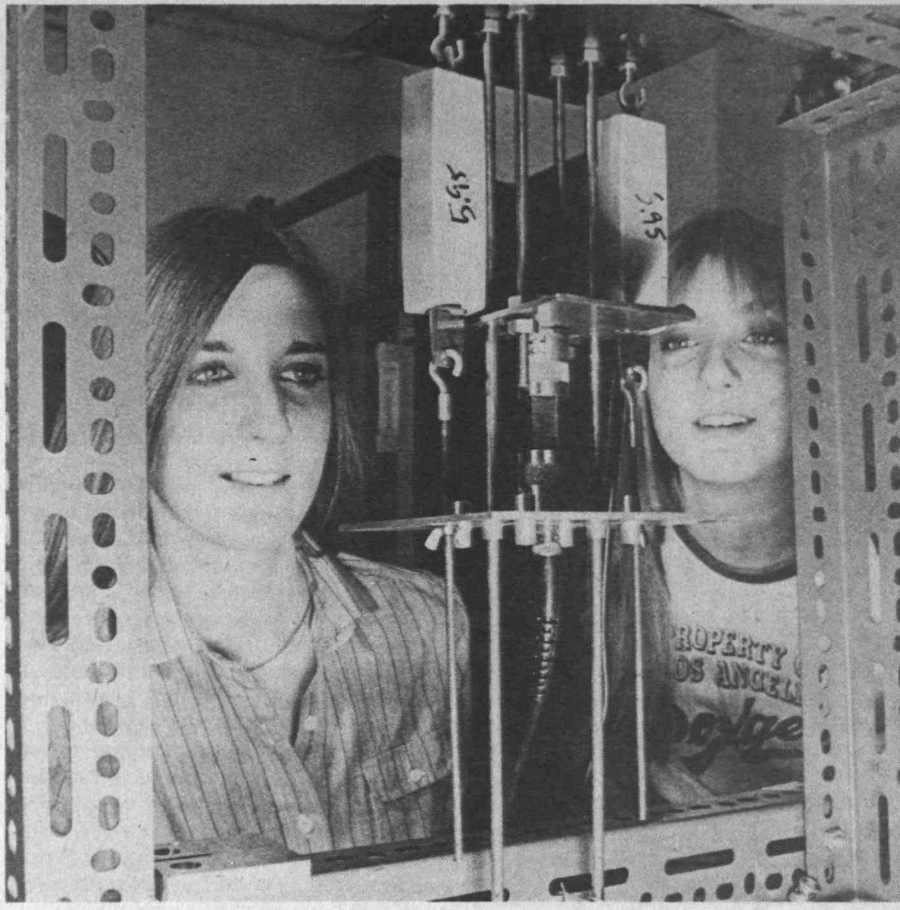
How to recognize that potential? "There is no simple way to make judgments," Peter Richardson says. "I am blessed with a staff that is sensitive to human beings; and we are continually trying to inform ourselves to make better decisions in the future. We are always challenged on the basis of the individual case."

I was reminded of the freshmen picnic in Killian Court: in the late afternoon sun in September I spotted Peter Richardson walking just in front of me into the large crowd, the first gathering of the M.I.T. Class of 1985.

"How did you feel at the freshmen picnic?" I asked him in his office two months later.

He sparkled. "It's a great high; I spent a lot of time just walking around. For a very few seconds they're mine, and there's nobody in this world prouder of them."—*M.L.*

Under the Domes



It all began when Beth Doll, '79, came to M.I.T. in 1975. She liked it so much that she's still here—working toward a doctorate in mechanical engineering. And when the time came she recruited her sister Clare Doll (right) for the Class of 1982. Indeed, Beth's enthusiasm was so contagious that the two sisters now work side-by-side with Professor James H. Williams, Jr., '67, on a research project in composite materials testing. (Photo: Calvin Campbell)

Class of 1985: Who Are They and What Will They Become?

Now that they're here, what's the new class like?

According to Walter D. Burnham, professor of political science who surveyed 80 new students at the Academic Midway late in September, this year's freshmen are politically more conservative than their predecessors—"a microcosm of the country at large."

Professor Burnham's impression is that "over the past several years, each entering group of freshmen who has taken the trouble to fill out the questionnaire has been slightly more conservative than the last." He doubts that "the overall response would have been quite so strongly conservative a decade or so ago."

But Professor Burnham admits that the annual surveys are small, and he suspects that most readers of this latest report will "seriously over-interpret it."

As for statistics: the class represents 26 foreign countries and every area of the United States, the highest number (32 percent) from the Middle Atlantic states. Class rank data show that in fact, over 875 of the class of 1,000 were in the top tenth of their high school class.

The admissions office looks carefully at scholastic achievement. Indeed, 509 members of the new Class of 1985 scored 750 or more on the College Entrance Examination Boards Math Level II Achievement Test, 196 on the Level I test; 156 were over 750 on the physics achievement test, 155 on chemistry achievement. And the scores on aptitude tests are high, too: 398 members of the new class were above 750 on mathematics aptitude, 65 in verbal aptitude.

But M.I.T. is also concerned with personal qualities that students have acquired during their years in secondary school: a need to set high standards and to strive toward challenging intellectual, cultural, and personal growth; the ability to write clearly and to analyze data to extract the underlying trends; a sensitivity to cultures and traditions other than their own.

During the time spent at M.I.T., "we must show them how to be responsible for their own education and encourage them always to reach a little beyond their grasp," says the official report to high school counselors from Peter H. Richardson, '55, director of admissions.—*M.L.*

An $11,000 Plea to the President

As of last June, the student activities budget administered by the Undergraduate Association's Finance Board was set at $81,500 by Shirley M. McBay, dean for student affairs—the same as it had been since 1973. But that "didn't make any sense at all" to John DeRubeis, '83, president of the Undergraduate Association, and at Dean McBay's suggestion he went to see President Paul E. Gray, '54.

It worked. "President Gray didn't realize that our budget had been frozen for so long," Mr. DeRubeis told *The Tech*, and he agreed that "the need for more funds existed." Result: an $11,000 mid-summer increase, bringing the total activities budget for 1981-82 to $92,600. The extra $11,000 went into "unallocated reserves," to meet "special requests" of clubs and other activities.

Taxable Pizza

Students are exempt from the Massachusetts meal tax, but—student or no—the pizza you buy from Joe O'Keefe, whose truck is a familiar evening fixture on the M.I.T. campus, is taxable. Joe didn't think so, and early this year he was more than a little dismayed when the Commonwealth of Massachusetts brought him a claim for over $4,000 in back taxes and $1,000 in penalties.

Even with 21 years in the pizza business, that's quite a blow. But it was softened a bit by some of Joe's student customers. They've contributed some $700 to help meet the unexpected bill—just as, early this fall, "a fellow with a bill of $6.10 handed me a $25 check," Mr. O'Keefe told Stuart Gitlow, '84, of *The Tech.*

A "dazzling selection of the best in 20th-century graphics," said The Tech *after going through the Hayden Gallery early this fall: the Catherine N. Stratton and Albert and Vera List Collections, all original works ready for students to borrow and hang in their rooms for the year. The demand was far bigger than the supply—more than 800 students signed up for just over 200 prints—and a lottery system was used to determine which students could have pictures and the order of their choices from the collection. "I'm still salivating," wrote* The Tech*'s critic. (Photo: Calvin Campbell)*

A Program for Minority Postdocs

As if to prove Isaac Colbert's point (*see above*), Professor Frank E. Perkins, '55, associate provost, announced during the summer a new postdoctoral program to bring five minority postdoctoral scholars to M.I.T. every year for two-year appointments as associates. They'll participate in teaching and research in the fields of their expertise with all the benefits and privileges of staff appointees. Emphasis in selection will be on fields "where minority representation has been low in the past" at M.I.T., says Professor Perkins, who will welcome applications and requests for further information.

Learning the Discount Business

The Bargain Book contains 243 discount coupons worth $1,058, and you could buy it last fall in Building 10 lobby for just $7—or at Northeastern, Harvard, Boston University, Simmons, and Wellesley for $8.

Why the $1 discount for M.I.T.? Because *The Bargain Book*'s entrepreneurs, operating under the name of Boston Promotional Services, Inc., are graduate students in the Sloan School of Management.

The idea first came to Curt P. Kohlberg and Timothy S. Sutton last spring when they chanced on a copy of the Stanford *Money Book*. Nothing like it in Boston, they thought, and there ought to be. Predecessors weren't indexed, didn't have the "quality discounts," and were too expensive for advertisers and customers alike.

Messrs. Kohlberg and Sutton spent the summer calling on "hundreds of stores." The problem, as it turned out, was not to make a sale but to get in the door. "If we got an appointment with the store, the probability that they would put a coupon in our book was 50 to 60 percent," they told Laura S. Farhie, '84, of *The Tech*. And the offerings were good—"the first selection of promotional discounts ever compiled in the Greater Boston area." No discount in the book is less than 15 percent, and there are lots of "buy-one-get-one-free" offers. Among the advertisers are 45 restaurants and bars, "the best night clubs in Fanueil Hall," the New England Aquarium, the Museum of Science, and 19 clothing stores, barber shops, and health care stores. One coupon alone will pay for the book in the hands of an unwary immigrant from the sun belt: $20 off on a goose down jacket.

$2.5 Million to Cambridge

Taxes paid to Cambridge on M.I.T.-owned real estate were more than $2 million in 1980-81. Including payments in lieu of taxes on certain educational properties, the Institute's total payments to Cambridge on the basis of its real estate were just under $2.5 million.

The taxable property is that which is not used for educational purposes—mostly held for investment. Payments in lieu of taxes are made on some properties recently transferred from investment to educational uses, the payments being designed to ease the city's problem when valuable property is suddenly withdrawn from the tax rolls.

Courses

C. Kaysen

Kaysen Heads STS, Lists Five Visitors and Their Projects

Carl Kaysen, David W. Skinner ('23) Professor of Political Economy since 1976, is now director of the Program in Science, Technology, and Society (STS) in the School of Humanities and Social Science.

Dr. Kaysen has been associated with the program since coming to M.I.T., but he was on leave from 1978 to 1980 to serve as vice-chairman and director of research of the Sloan Commission Report on Higher Education. Before coming to the Institute, Professor Kaysen was for ten years director of the Institute for Advanced Study in Princeton, N.J., and previously held faculty posts in economics at Harvard.

Now back at M.I.T. full time, Dr. Kaysen has announced five appointments to the program for the current year:

☐ Harley Balzer, fellow at the Harvard Russian Research Center, will be visiting fellow at M.I.T. working on a study of the "style" of Russian and Soviet engineers.

☐ John Bloomfield, professor of history at the University of Michigan, is visiting fellow to work on a study of changing U.S. images of "progress" and "advancement."

☐ Julian Gresser, professor of law at the University of Hawaii, will study Japanese policy on investments in new technology as part-time visiting professor.

☐ Martin Krieger, formerly visiting assistant professor in urban studies and planning at M.I.T., now joins the STS Program to continue a project on scientists and their work methods and ethics.

☐ David E. Nye, director of American studies at Union College, will spend the year as visiting scholar at STS studying the photographic archives of General Electric Co. as a project in industrial history.

☐ John H. Weiss, assistant professor of history at Cornell, will complete a study of the French engineering profession during a one-year visiting professorship at STS.

I
Civil Engineering

Professor **Michael D. Meyer,** Ph.D.'76, whose teaching and research are in transportation planning, policy, and organizational analysis, now holds a Class of 1922 Career Professorship—a post designated for "young faculty members of exceptional promise and unusual devotion to teaching." Professor Meyers is already a Danforth Fellow, an honor in recognition of his concern for undergraduate education, and he's credited with several changes in subjects taught by the department.

John Stanley-Miller, Ph.D.'74, reports, "I have been appointed director of the Division of Analytical Services with the U.S. Department of Energy. Analytical Services provides the Office of Policy, Planning, and Analysis with projections and analysis of energy demand, supply and prices through the year 2000. I am a member of the government Senior Executive Service and have been working in the Department of Energy for three years." . . . **John P. Dugan,** S.M.'68, has been promoted from project engineer to an associate in the firm of Haley & Aldrich.

II
Mechanical Engineering

Jacob P. Den Hartog, former head of the department who is now professor of mechanical engineering emeritus, was honored last fall with the James Watt International Medal of the Institution of Mechanical Engineers (London). The presentation, honoring applications of science for the progress of mechanical engineering, was part of the 1981 convention of the American Association of Engineering Societies in Pittsburgh.

Professor **Ronald F. Probstein,** is co-author of *Synthetic Fuels,* a book which emphasizes the scientific and engineering principles underlying the methods and processes for converting coal, oil shale, tarsands, and biomass into clean liquid, gaseous, and solid fuels.

III
Materials Science and Engineering

Klaus Zwilsky, Sc.D.'59, writes, "After 14 years with the Atomic Energy Commission and its successor organizations, the Energy Research and Development Administration and the Department of Energy, I am leaving government service to assume new responsibilities as executive director of the National Materials Advisory Board of the National Academy of Sciences. I am looking forward to some exciting times in helping to define materials needs on the national level and interacting with materials people all over the country. My work during the past eight years in the DOE has been with the Magnetic Fusion Energy Program, in charge of funding materials programs for fusion. As for family matters, Bobbie, my wife of 25 years, is an information analyst with TERA Corp., whose work is to computerize the data information system for the Nuclear Regulatory Commission. My son Mark, 23 years old, is working in the Washington, D.C., area, and my daughter Ellen, 20 years old, is a junior at George Washington University."

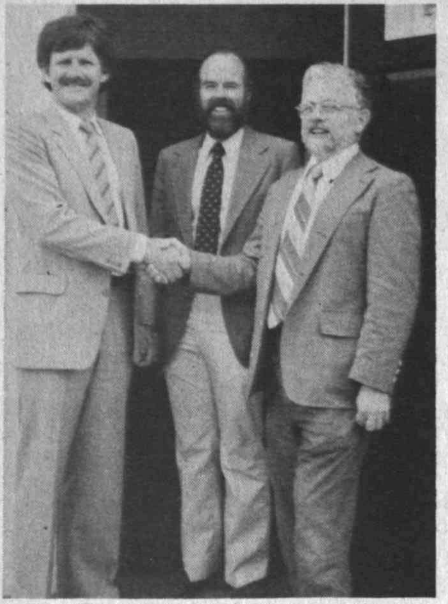
Charles J. McMahon, Sc.D.'63, professor of metallurgy and materials science at the University of Pennsylvania, has been selected to receive the Albert Sauveur Achievement Award by the American Society for Metals. His work with M.I.T. Professor Emeritus Morris Cohen—on initiation of cleavage in iron—formed the basis for his later study in that area. . . . **Richard E. Mistler,** Sc.D.'67, vice president of research and development of Frenchtown American Corp., Frenchtown, N.J., has been elected a fellow of the American Ceramic Society in recognition of his contributions to ceramic and microelectronic sciences, arts, and industry. . . . **Charles W. Finn,** Ph.D.'71, has been appointed associate professor with responsibility for pyrometallurgy in the Department of Metallurgy at the University of Witwatersrand, Johannesburg, South Africa.

V
Chemisty

Robert A. Laudise, Ph.D.'56, holds the 1981 $3,000 Crystal Growth Award of the American Association for Crystal Growth. Dr. Laudise, who is director of the Physical and Inorganic Chemistry Laboratory at Bell Labs, pioneered in the synthesis of crystals for applications in modern electronics; he is a past president of AACG, president of the International Organization for Crystal Growth, and a member of the Corporation's Visiting Committee to the M.I.T. Department of Materials Science and Engineering.

William R. Rousch, assistant professor of chemistry at M.I.T. since 1978, is now the Roger and Georges Firmenich Career Development Assistant Professor of Natural Products Chemistry. He's been active in the field of natural products chemistry and synthesis, in the biosynthesis of dextran, and in the synthesis and biological characterization of environmental pollutants. Professor Rousch succeeds **William Rastetter,** first holder of the Firmenich chair, who became associate professor during the summer.

Stephan J. McLain, Ph.D.'79, writes that in 1979-80 he was a Miller Research Fellow of the Miller Institute for Basic Research in Science at the Uni-



New strength for Langley-Ford Instruments. Peter R. Wallace, S.M.'74 (left), has joined the Amherst-based company as chairman of the board and brought with him additional equity financing for the company which specializes in applying digital correlation technology to the design of scientific instruments. With him in the picture are Kenneth H. Langley, '58, vice-president, and Norman C. Ford, Jr., '53 (right), president. Drs. Langley and Ford are members of the Physics Department at the University of Massachusetts.

$1 Million from Toyota for Materials Processing

A $1 million gift from the Toyota Motor Co., Ltd., of Tokyo will support the Toyota Professorship in Materials Processing at M.I.T.—another in the company's many efforts to "deepen the mutual understanding and friendship between Japan and the U.S.," says Eiji Toyoda, president of Toyota.

Expressing M.I.T.'s response, President Paul E. Gray, '54, called the area of materials processing a "critical" one for U.S. technology, and he said the new gift will strengthen M.I.T.'s leadership in it. And he noted that Itaru Niimi, a managing director of Toyota, spent the spring term of 1980 studying in that field at M.I.T. and thereafter became a founding professor in the newly opened Toyota Technological Institute in Nagoya, Japan; Dr. Gray himself was a principal speaker at ceremonies in April, 1981, marking the opening of that institute.

versity of California, Berkeley. Currently he is employed at the Central Research and Development Department of E.I. du Pont de Nemours and Co., Wilmington, Del. . . . **Robert Nelson,** Ph.D.'69, is presently assistant professor of chemistry at Georgia Southern College, Statesboro, and spends the spring and summer quarters at the University of Georgia as a visiting lecturer and postdoctoral fellow doing laser spectroscopy with **Lionel Carreira,** Ph.D.'69.

Anthony P. Malinauskas, Ph.D.'62, head of the Chemical Development Section at the Oak Ridge National Laboratory, has won an American Nuclear Society Special Award for Advancements in Nuclear Technology in response to the Three Mile Island accident. He and two colleagues, resolved one of the puzzling aspects of TMI—the almost negligible release of radioactive iodine-131. . . . **William R. Moomaw,** Ph.D.'65, has been named the William R. Kenan, Jr., Professor of Chemistry by Williams College, Williamstown, Mass. . . . **John E. Wood III,** Ph.D.'39, reports, "I retired as vice-president, Oil and Gas Division, for Vulcan Materials Co. on May 31, 1981, following 16 years of service in various positions with the company. I plan to continue as a consultant and a director of Vulcan's oil and gas subsidiary. I don't seem to have any problem in keeping busy during my so-called retirement. I am at this time serving as president, Area IV (Alabama-Mississippi) of the Boy Scouts of America and on the Executive Committee of the Alabama Chamber of Commerce. I also serve on the President's Council of the University of Alabama, Birmingham, and am a member of the Advisory Committee of the School of Mining and Energy Development of the University of Alabama as well as of the Corporation Development Committee of M.I.T. I also serve as a National Trustee of Ducks Unlimited and on the Board of the Alabama Wildlife Federation."

VI
Electrical Engineering and Computer Science

Alvin W. Drake, '58, professor of systems science and engineering in the department, is now the Cecil H. Green ('23) Professor. He'll use the professorhip to study in the field of risk assessment, a supplement to his earlier work in applied probability, decision analysis, and the application of operations research to such public systems as blood banks.

John A. Hook, Jr., S.M.'80, reports that he is presently a Captain in the U.S. Army teaching mathematics at the U.S. Military Academy, West Point, N.Y. . . . Mitre's Corp.'s Metrek Division W-40 has been divided into two divisions, with **Howard J. Kirshner,** '54, as director of Transportation Systems and **J. Paul Locher III,** '58, as technical director of Transportation Systems Engineering. . . . **Marc S. Seriff,** S.M.'73, has been appointed vice president of quality management at GTE Telenet Communications Corp., Vienna, Va., responsible for developing and monitoring quality programs and standards of the company's data network and electronic mail operations. . . . **Donald M. Gaylord,** S.M.'68, is presently supervisor with the Switching Network Maintenance Group at Bell Labs, Denver, responsible for switching network maintenance software for the Private Branch Exchange (PBX) product line.

VI-A Program

This summer found the largest number of VI-A students in the program's history working at companies in the Palo Alto-San Jose area of California: 42 to be exact. The companies having these students included: Fairchild, Hewlett-Packard, IBM, and Xerox. On August 9, 1981, the majority of these students gathered in Braly Park in Sunnyvale for the Third Annual West Coast Picnic sponsored by the VI-A office. **Denice D. Denton,** '81 (Fairchild) acted as chief co-ordinator of this very successful affair.

Cecil H. Green, '23, hosted the annual TI VI-A luncheon at the Petroleum Club in Dallas on August 13, 1981. Some 40 VI-A students, their managers, and corporate officials of Texas Instruments, Inc. attended this affair which has become a wonderful tradition under Mr. Green's leadership.

This summer, for the first time, Director Tucker was unable to attend either of these traditional events. Travel plans were complicated by the airlines controllers' strike and attendance at three funerals as Deacon of his church.

Tektronic, Inc., has successfully completed its first summer with three VI-A students working at the company's Beaverton, Ore., facilities: **David A. Chan,** '82, **Robert H. Leong,** '83, and **Steven J. Silberberg,** '83. **Steven Swerling,** '63, who performed yeoman service in bringing Tektronic onto the program, has left to become vice president of engineering of Mentor Graphic, Portland, Ore. We wish him success in this new position! **Robert G. Rullman,** '51, who interviewed for VI-A at M.I.T. this spring, has taken over from Steven as Tektronix's VI-A co-ordinator. Professor **Richard D. Thornton,** '54 visited Tektronix in June, so this transition should proceed smoothly.

Another change of command has taken place at the Hewlett-Packard Co. **Paul E. Stoft,** '49, an assistant professor in this department in 1956, has been appointed by H-P's president, John Young, to be chief co-ordinator for VI-A for all of H-P's divisions. He replaced **William A. Rytand,** '65, who left H-P last June. Dr. Stoft is currently assistant for technical and college relations to Vice President John Doyle who is the newly appointed director of H-P laboratories, Palo Alto, Calif.

Congratulations are due for **Harold T. McAleer,** '52, who has been promoted to senior vice president of GenRad, Inc., Concord, Mass. GenRad is a VI-A company employing a number of M.I.T. alumni, including its president, **William R. Thurston,** '44.

Other news of VI-Aer's: **Steve L. Bates,** '74 has joined GenRad, Inc., West Concord, Mass.; **Mark T. Fuccio,** '80, has left North American Phillips for Trilogy Systems Corp., Santa Clara, Calif.; and **Arthur T. Hu,** '80, whom Director Tucker met recently in Framingham, is with Digital Equipment Corp., Hudson, Mass. While attending this summer's VI-A project presentations at Lincoln Laboratory, Director Tucker met **Vincent W. Chan,** '71 and **Jeffrey D. Kurtze,** '71. Jeff, incidentally, teaches evenings at M.I.T. Lowell Institute School. We learned from his wife **Christine (Plapp),** '75, who visited the VI-A office, that husband **Karl M. Lofgren,** '75, has joined Western Digital, Irvine, Calif.

Other alumni/ae visitors to the VI-A office since our last article have included: **Henry B. Backenstoss,** '34, now retired; **Eric D. Black,** '77, visiting from the West Coast where he works for FA/Gould; **Donald L. Brinkley,** '79, with Magnavox Data Systems, Inc., Falls Church, Va.; and **Joshua L. Koslov,** '79, with RCA, Princeton, N.J.—John A. Tucker, director, VI-A Program, Room 38-473, Cambridge, MA 02139

VIII
Physics

Albert D. Wheelon, Ph.D.'52, has been named senior vice president and group president of the space and communications group of the Hughes Aircraft Co., Culver City, Calif. . . . **Timothy Fohl,** S.M.'59 has been named manager of photo optics and high intensity discharge research at GTE Lighting Products, Salem, Mass. . . . **Hans Mark,** Ph.D.'54, has been named by President Ronald Reagan to be Deputy Administrator for NASA. He was Secretary of the Air Force during the Carter administration, and for 11 years he had been Director of NASA's Ames Research Center. Prior to that he was chairman of the Nuclear Engineering Department at the University of California.

William J. Ozeroff, '42, a physicist and a leader in the development of nuclear power reactors, passed away on June 19, 1981. He managed large reactor research and development groups for General Electric at Hanford and at the Vellecitos Nuclear Center, Pleasonton, Calif. In 1961 he took a two-year leave of absence from Vellecitos to help France develop nuclear energy for peaceful pur-

BRADFORD F. HERZOG

A.J. Silk

Silk Named Associate Dean

Professor Alvin J. Silk, coordinator of the marketing group in the Sloan School of Management, has been named associate dean of the school. He'll assist Dean Abraham J. Siegel with general administration of the school with special emphasis on graduate education and research.

Professor Silk studied at the University of Western Ontario and Northwestern University and taught at the University of California in Los Angeles and the University of Chicago before coming to M.I.T. in 1968. His own research has been on advertising testing and policymaking; as head of the marketing group he has led studies designed to improve the effectiveness of marketing decisions.

P.H. Stone

Stone Heads Meteorology

Professor Peter H. Stone, an authority on planetary atmospheres and the general circulation of the Earth's atmosphere, is now head of the Department of Meteorology and Physical Oceanography. He succeeds Professor Edward N. Lorenz, who had been department head since 1977.

Professor Stone came to M.I.T. in 1972 as visiting professor of meteorology, when he was a member of the faculty at Harvard. He came to the Institute permanently in 1974, after two years as a staff meteorologist at NASA's Goddard Institute for Space Studies. Professor Stone's degrees are from Harvard, and he first taught there as a junior fellow in the Society of Fellows in 1961 while a graduate student.

poses. . . . **Ludwig Katz,** '49, of Swampscott, Mass., passed away on March 18, 1981; no details are available.

X
Chemical Engineering

A. David Rossin, S.M.'55, writes that is is currently Director of the Nuclear Safety Analysis Center at the Electric Power Research Institute, Palo Alto, Calif. . . . **Jerry McAffee,** Sc.D.'40, will retire on November 30, 1981, as chairman and chief executive officer of Gulf Oil Corp., Pittsburgh, Penn. . . . **Allan H. Bergman,** S.M.'58, formerly vice president and general manager of Permabond International Corp., Englewood, N.J., has been named its president.

Samuel M. Fleming, Sc.D.'70, has been appointed manager of technology development for Fluor Engineers and Constructors, Inc., Irvine, Calif., responsible for the investigation, evaluation, and development of sources of technology which will maintain and improve the firm's engineering and construction capabilities. . . . **Eliot M. Rosen,** S.M.'75, reports that in 1979 he received an M.D. degree from the University of Pennsylvania Medical School and in August 1980 was awarded a Ph.D. from the University of Pennsylvania in physiology. His dissertation topic was "The Use of Cultural Vascular Endothelial Cells as an In Vitro Model for Cellular Senescence." In 1981 he completed his internship at Beth Israel Hospital, Boston, and then began his residency which will terminate in 1984 in radiation therapy at Harvard's Joint Center for Radiation Therapy.

Ralph Landau, Sc.D.'41, has been elected vice-president of the National Academcy of Engineering and will serve until June 30, 1982; he is chairman of the board and chief executive officer of the Halon SD Group, Inc. . . . **A. David Rossin,** S.M.'55, is currently head of the American Nuclear Society Public Policy Committee and director of research for the Commonwealth Edison Co.

XI
Urban Studies and Planning

John Kilburn Bullard, M.C.P.'74, the agent for the Waterfront Historic Area League (WHALE), New Bedford, Mass. was married on June 28, 1981 to Anne Warring Dunbar. Anne is currently working on a degree in psychology at Southeastern Massachusetts University and is administrative assistant at Friends Academy in North Dartmouth. . . . **Alonzo William Lawrence,** S.M.'60, formerly vice-president, environmental resources and occupational health of Koppers Co., Inc., Pittsburgh, Penn., has been appointed vice-president of science and technology, responsible for all research and development activities. . . . **Mary Breuer,** M.C.P.'72, has recently joined the firm of Hellmuth, Obata & Kassabaum, Inc., St. Louis, Mo., as director of business development/program management, responsible for marketing the facilities planning service.

XIII
Ocean Engineering

Chryssostomos Chryssostomidis, Ph.D.'70, associate professor of naval architecture, has been acting head of the M.I.T. Department of Ocean Engineering since early this fall, when Professor **Ira Dyer,** '49, left that post to devote full time to research and teaching in acoustics, vibration, and noise control.

Professor Chryssostomidis, who was appointed to the faculty upon completing his doctorate in 1970, is closely associated with the department's design curriculum and its program of ship design research. His most recent studies have involved possible applications of coal-fired power plants to modern cargo vessels.

Manfred Kling, S.M.'80, reports that he is a naval architect, special projects officer at the Canadian Naval Engineering Unit Pacific, Esquimalt, British Columbia, Canada. . . . **Jennifer J. Zeien,** S.M.'80, is presently a research associate in Maritime Group at Temple, Barker, and Sloane, Inc., Lexington, Mass.

Theodore J. Fabik, S.M.'41, passed away on August 7, 1981, as reported by his wife Margaret.

XIV
Economics

George P. Shultz, Ph.D.'49, president of Bechtel Group Inc., has been named a director of the General Motors Corp., Detroit, Mich., and also named to its Finance Committee. Formerly he was Secretary of the Treasury, Secretary of Labor and Director of the Office of Management and Budget in the Nixon-Ford administrations.

XV
Management

Professor Emeritus **Carroll L. Wilson,** '32, formerly the Mitsui Professor in Problems of Contemporary Technology in the Sloan School, has received the $100,000 John and Alice Tyler Ecology/Energy Prize for 1981. Professor Wilson was cited for his role in helping found the International Centre for Insect Physiology and Ecology in Nairobi and in organizing studies of critical environmental problems, climatic change, and alternative energy strategies. The prestigious prize was founded in 1973 by the late John C. Tyler, cofounder and chairman of the Farmers Insurance Group. and his wife Alice.

Terry Rothermel, Ph.D.'70, is currently a water management consultant for Arthur D. Little, Inc., Cambridge, Mass. His current research efforts indicate that industry and water usage patterns and conservation techniques are improving; a variety of forces, including economics, he says have brought industry to recognize that water is not a free commodity in endless supply and that new approaches to water use are necessary. . . . **Kenneth W. Gorman,** S.M.'75, was married this past August to Catherine Madeline McMahon, a graduate of the University of California, Los Angeles. Kenneth is presently director of long range planning and product manager of AMECRM, Bedford, Mass. The couple is residing in Manchester, Mass.

Ralph P. Baker, Jr., S.M.'41, has been named market manager, medical instruments of Corning Glass Works, Corning, N.Y. . . . **Alan Pasnik,** S.M.'73, has been elected vice president of circulation and fulfillment of Warren, Gorham & Lamont, Inc., Boston, Mass., a publisher of legal and business texts, periodicals, and newsletters. . . . **Alexis D. Falquier,** S.M.'67, has been named director of the senior management group of McKinsey & Co., Mexico City.

Michael G. Smith, S.M.'73, has been promoted from senior manager to vice president of TMI's Investment Systems Group, Lexington, Mass. . . . **John E. Wolfe,** S.M.'74, has been named senior vice president, North American operations, for EG&G Sealol, Inc., Warwick, R.I., responsible for all U.S. operating divisions as well as EG&G Sealol Canada.

Sloan Fellows

Colby H. Chandler, S.M.'63, president of Eastman Kodak Co., has been named a director of the Continental Group, Inc., Stamford, Conn., a firm with interests in packaging, forest products, insurance, and energy. . . . **Charles M. Laidley,** S.M.'65, has resigned as vice chairman of Canadian Imperial Bank of Commerce and as director of Massey-Ferguson, Ltd., Toronto, Canada. . . . **David L. Chapman,** S.M.'70, former director of data processing manufacturing for International Business Machines Corp., has been named vice president, U.S. manufacturing, of Data General Corp., Westboro, Mass.

Rudolf Rentsch, S.M.'68, has been named president and chief executive officer of Revere Aluminum Southeast, a newly formed division of Revere Copper and Brass, Inc., New York, N.Y., a maker of fabricated aluminum, copper, and brass. . . . **Victor C. Meyer,** S.M.'67, has been named a vice president of AM International, Inc., Los Angeles, Calif., and continues as a president of an AM division. . . . **Donald H. White,** S.M.'70, has been appointed senior vice president-controller of the Hughes Aircraft Co., Culver City, Calif.

John Beckwith, S.M.'58, vice president of technical services of Associated Spring, Barnes Group, Bristol, Conn., passed away on June 23, 1981. In 1946 following three years of naval service as a radar officer during World War II, he began his 35-year career with Barnes Group, Inc. He also served as director of Bristol Federal Savings & Loan, an incorporator of Bristol Hospital, and a past president and director of Spring Manufacturers Institute. . . . **Alberto Jimenez,** '68, of Chosica, Peru, passed away on May 17, 1981; no details are available.

William S. Nochisaki, S.M. '60, was named vice-president, advanced manufacturing technology, of the Homelite Division of Textron, Inc., Charlotte, N.C. . . . **Richard P. de La Chapelle, Jr.,** S.M. '74, has been named vice-president and general manager, special products division, at GTE Lighting Products, Stamford, Conn. . . . **Hugh E. Witt,** S.M. '57, currently vice-president, government liaison, United Technologies Corp., has been elected chairman of the Council of Defense and space Industry Associations and chairman of the Policy committee for the year July 1, 1981 through June 30, 1982, selected to represent the Aerospace Industries Association.

Senior Executives

Eugene L. Schotanus, '73, formerly vice president and treasurer of Deere & Co., Moline, Ill., has been elected a senior vice president and director of this maker of farm, industrial, and consumer outdoor power equipment. . . . **Ralph Hennie,** '76, reports that in August, 1979 he was promoted to general manager of the Steel and Tubes Division, Republic Steel Corp.

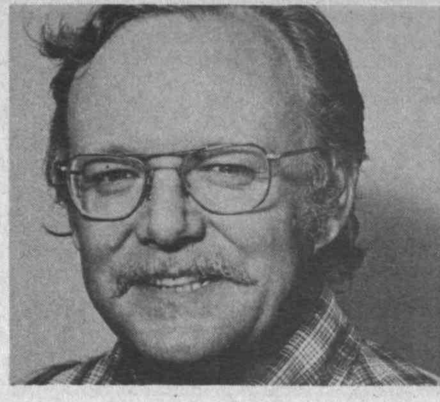
Gustav Dick, '65, of Moline, Ill., passed away on April 10, 1980, as reported by his wife. . . . **Hassan S. Mohamed,** S.M.'60, passed away in 1974, the Alumni Association was recently informed. . . . **William A. Keeler,** 63, vice-president/research for ARCO Oil and Gas Co., Dallas, Tex., passed away suddenly in July 1981. . . . **Robert E. Conary,** '61, associated with Texaco Services, Ltd., Brussels, Belgium, passed away this year; no details were given.

XVI

Aeronautics and Astronautics

Henry Faery, S.M.'69, reports that he has retired from the army on July 31, 1981, after a 21-year career, and will begin work as an engineer consultant with Stone & Webster Engineering Corp., New York City. . . . **Paul S. Basile,** S.M.'72, writes, "I have moved again—to Geneva this time. I am with a new, small private international company, International Energy Development Corp. and we are signing deals with Third World governments to search for oil." . . . **Richard L. Adams,** '71, is presently assistant professor of mechanical engineering at Oregon State University. . . . **George Stalk,** S.M.'74, reports that he received an M.B.A. from Harvard University, Cambridge, in 1978. "I am a manager of Boston Consulting Group and am assigned to the Tokyo office of the company. Wife and cat doing well." . . . **Martin C. Jiscke,** Ph.D.'68, has been appointed dean of the College of Engineering at the University of Oklahoma, Norman.

James L. Nash-Webber, Sc.D.'68, glider pilot, editor, instructor, scientist, passed away on July 10, 1981. He was a visiting scientist at the Institut Cerac, Ecublens, Switzerland and had taken a one-year leave of absence as a research scientist in the M.I.T. Energy Laboratory. He was president from 1975-76 of the Soaring Association of M.I.T., associate editor and chairman of the technical board of the Soaring Society of America, and a member of the test pilot panel for NASA program in 1976.



K.L. Hale

Ward Professorship to Hale

Kenneth L. Hale, one of the world's few specialists on the languages of native Australians and Americans, is now Ferrari P. Ward ('26) Professor in the Department of Linguistics and Philosophy. He succeeds Professor Morris Halle, recently appointed Institute Professor.

Dr. Hale holds degrees in anthropology from the Universities of Arizona and Indiana, and he came to M.I.T. in 1967. Since then he has carried out extensive field work on five American Indian and several Australian Aboriginal languages—work which is "at the forefront of research in these languages and their implications for a theory of universal grammar." The work, says Professor Samuel J. Keyser, '77, who heads the department, reflects Professor Hale's "strong commitment to other cultures and their need to survive intact."

XVII

Political Science

Willard R. Johnson, professor of political science, has urged in a *Boston Globe* op-ed essay that Massachusetts state employees' pension fund accounts be divested of bonds and stocks in U.S. companies operating in South Africa. There is "a growing tide of international opposition to South African policies and the support the Reagan administration has proposed to give to the white minority regime there," Professor Johnson writes. Indeed, he says,

"the South African regime is the most racist and oppressive in the world. The majority of its citizens are denied the most basic human rights. . . . The overall picture is one of system oppression of the majority by a distinct minority." About $130 milion is involved, he says, and Professor Johnson argues that his proposal, in addition to eliminating "our public complicity in oppression," would "improve the pension fund portfolio and increase the return to pensioners and the Massachusetts economy."

Professor **Nazli Choucri,** has recently written *International Energy Futures: Petroleum Prices, Power, and Payments,* published by the M.I.T. Press. The book deals with the international petroleum trade, providing a view that departs from the conventional perspective. . . . **Richard A. Johnson,** S.M.'74, presently with Arnold and Porter, Washington, D.C., writes that "following my Ph.D. days at M.I.T. I have focused on Japanese trade and technology while continuing to maintain my private practice. During my recent tenure as general counsel for international trade in the Commerce Department, I chaired the U.S.-Japan Trade Review."

XVIII
Mathematics

Professor **Nesmith C. Ankeny** has written a book *Poker Strategy—Winning with Game Theory,* published by Basic Books. Professor Ankeny generally dismisses luck and psychology as important elements in poker and prefers instead an optimal strategy, "the one that brings the maximum guaranteeable profit over the long run when you are confronted with opponents whose responding strategies you cannot predict."

XIX
Meteorology

Athelstan F. Spilhaus, S.M.'33, who has a distinguished career in ocean and atmospheric science and policymaking, received the 1981 Compass Distinguished Achievement Award administered by the Marine Technology Society during the Oceans '81 Conference in Boston last fall. In addition, MTS announced that its series of conferences and short courses would be named in Dr. Spilhaus' honor. "We know of no one who has made so many contributions to ocean science and technology," said Arthur E. Maxwell of Woods Hole Oceanographic Institution, 1980-81 president of MTS. . . . **Veshpati Manohar-Majaraj,** S.M.'73, writes, "I am still working with Schlumberger and am training center manager in Venezuela with our latest computerized unit."

XX
Nutrition and Food Sciences

Felix Bronner, Ph.D.'52, writes, "I have continued my teaching and research at the University of Connecticut Health Center. Organized a very successful workshop in Vienna, Austria (March, 1981) on transport across biomembranes. I have also co-edited a book, *Disorders of Mineral Metabolism,* to be published later this year by Academic Press." . . . **Alina Szczesniak,** Sc.D.'52, a principal scientist at General Foods Corp., has been elected a Fellow of the Institute of Food Technologists, cited as "an internationally recognized authority on food texture." . . . **Anthony J. Sinskey,** Sc.D.'67, professor of applied microbiology at M.I.T., reports that he has been appointed associate director of Sea Grant Research Coordination for the period of 1980-1983. He was also the recipient of the "Hot Pack" Lectureship Award from the Canadian Society of Microbiologists in June, 1981.

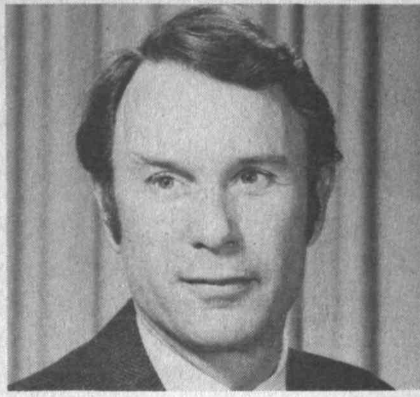
Charles T. Freedman, S.M.'56, an associate professor and tennis coach at Massachusetts Maritime Academy, Buzzards Bay, passed way on July 19, 1981. He began his career at Mass. Maritime in 1971, as a teacher of calculus and physics. At the time of his death, he was an associate professor of mathematics and science and recently received his doctorate degree from New York University. He also taught at Massachusetts College of Pharmacy and at Wentworth Institute of Technology and served as a consultant for Raytheon Data Systems.

XXII
Nuclear Engineering

Richard A. Loretz, S.M.'80, writes, that he is presently a reactor physicist, advanced design projects, for Combustion Engineer, Inc., Windsor, Conn. His major work topic is extended burnup, low leakage, PWR fuel management by use of gadolinium burnable absorber rods. The project includes development of transport methods for the modeling of gadolinium.

TPP
Technology and Policy Program

Bob Desourdis, '80, is working for Signatron, Lexington, Mass., as an engineering specialist and is doing consulting work on communications and communications systems. . . . **Jeff Bailey,** '81, is working for Shell Oil Co., Houston, Tex., in their computer programming and geophysics department. . . . **Barbara Herrmann,** '81, has formed Consulting Resources Corp., Lexington, Mass., an international management consulting firm providing services to executives concerned with the companies products and people of the chemical process industries. . . . **Bill Dunbar,** '79, and Richard de Neufville climbed Mount Olympus (Washington state) this past July.—Professor Richard de Neufville, chairman, Room 1-138, M.I.T., Cambridge, MA 02139.



D.L.M. Blackmer

Blackmer Heads Political Science

Donald L.M. Blackmer, who has been associate dean of the School of Humanities and Social Science since 1973 and director of the Program in Science, Technology, and Society since 1977, will return to his original academic field as head of the Department of Political Science early next year.

Professor Blackmer succeeds Professor Alan A. Altshuler, who will return to full-time teaching and research—the latter as co-director of the international program on the future of the automobile in the M.I.T. Center for Transportation Studies.

Professor Blackmer came to M.I.T. in 1956 even before he completed his graduate studies at Harvard to be executive assistant to the director of the Center for International Studies. He became assistant professor of political science in 1961 and was executive officer of the department for 1972-73, before becoming full professor.

A commanding view of the Charles River and wings at oblique angles to provide spacious courtyards are the two most visible features of 500 Memorial Drive, M.I.T.'s newest undergraduate residence which opened this fall. The large south-facing windows are part of a modest passive solar heating system which includes high-density concrete for heat storage. Installation of an active solar system was impractical because of cost, according to Paul F. Barrett, director of physical plant.

Housing: Good Risk, New Dorms, and Undergraduate Pressures Ease

With 350 new beds ready in M.I.T.'s newest dormitory—for the present, at least, it's known only by its address: 500 Memorial Drive—the housing shortage which has demoralized overcrowded undergraduates for the last five years was suddenly eased this fall. Indeed, with a successful Rush Week and all transfer students accommodated, at least a dozen spaces in the undergraduate houses were available to graduate students, who remain victims of a serious housing shortage at M.I.T.—and in Greater Boston.

By the end of Rush Week, 375 members of the Class of 1985 had joined fraternities—25 more than the goal set by the Interfraternity Conference, though some houses still had a few vacancies. The number of freshmen entering the fraternities this fall was larger than the number of seniors who left last spring, according to Mark Goldberg, '82, IFC's rush chairman.

By contrast, graduate student housing remained tight. Dean Kenneth R. Wadleigh, '43, of the Graduate School estimates that graduate enrollment is up about 150 this year over last; and even then demand for housing was "far in excess" of capacity, according to Sharon Lee, president of the Graduate Student Council.

A small ray of light for graduate students came during the fall, when Peter Brown, assistant dean for residence programs, announced that the Infirmary on Memorial Drive (the former Sancta Maria Hospital building) will be converted into graduate housing upon completion of the new Health Services Building at the end of this year. There will be room for between 50 and 64 students, Dean Brown said, when renovations are completed in September 1982.

The new building at 500 Memorial Drive represents a $10 million investment of M.I.T. funds and government loans. It's a single, integrated building with its own dining hall, lounge, and game rooms—and with a snack bar and grill area operated after hours as a West Campus social center.

Setting Affirmative Standards

Though the federal pressure for equal opportunity and affirmative action programs in colleges and universities may ease, M.I.T.'s effort will not, says Isaac M. Colbert, assistant equal opportunities officer.

"We didn't spend ten years erecting a policy and framework simply to discard it when the federal government takes the heat off," Mr. Colbert told Jon D. Morrow, '85, of *The Tech* this fall. The lack of federal pressure "puts pressure on leading institutions such as M.I.T. to set an example."

S. Curtis Powell, 1915-1981

S. Curtis Powell, '37, professor of marine engineering emeritus who taught at M.I.T. from 1948 to 1976, died on August 28 in Phoenix, Ariz.; he was 66.

Following study at the University of Genoa, Professor Powell was for ten years on the engineering staff at the Shipbuilding Division (Quincy) of the Bethlehem Steel Co. He returned to M.I.T. in 1948 to play a major role in teaching naval architecture and shipbuilding and to conduct important research on propeller design for marine propulsion systems. Professor Powell retired in 1976 and lived in Phoenix thereafter.

Cecil G. Dunn, 1904-1981

Cecil G. Dunn, '30, associate professor of industrial microbiology emeritus in the Dept. of Nutrition and Food Science, died in Tucson, Ariz., on August 12 following a long illness. He was 77.

Dr. Dunn served M.I.T. in the field of food technology for his entire professional career following receipt of his Ph.D. degree (1934) here. He taught undergraduate and graduate courses in industrial microbiology, food chemistry, bacteriology, and germicides and disinfectants, and he conducted research on industrial uses of bacteria, yeasts, and molds in the formation of fermented foods, acids, antibiotics, and enzymes.

Dr. Dunn was associate editor of *Food Technology*, founder and principal officer of the Boston Bacteriological Club, founder and president of the Northeast Branch of the American Society for Microbiology, a member of the Scientific Advisory Council of the Refrigeration Research Foundation, and co-author with the late Professor Samuel C. Prescott, '94, of *Industrial Microbiology*, a revised edition of which appeared under Dr. Dunn's authorship following Professor Prescott's death. Dr. Dunn served in the office of the Quartermaster General during World War II and later as commander of the 1001st Army Reserve Research and Development Group, and for ten years beginning at the time of his retirement in 1969 he was a consultant to the Carnation Co., Los Angeles.

William A. Baker, 1912-1981

William A. Baker, '34, curator of the Francis Russell Hart Nautical Museum from 1963 until his retirement this year, died on September 8 at his home in Hingham after a long illness; he was 69.

Mr. Baker, first employed for 30 years in the Shipbuilding Division (Quincy) of the Bethlehem Steel Co., had a life-long interest in maritime history. He began making replicas of historic ships in 1949, when he designed a restoration of Amundsen's *Gjoa*, the first vessel to complete the Northwest Passage; later he was the designer—among others—of the *Mayflower II* (the replica now a feature of the "Plimouth Plantation") and the *Beaver II* (the Boston Tea Party ship which is now a tourist attraction in Boston).

In addition to his assignment as curator of the Hart Museum, Mr. Baker was a part-time lecturer in the Department of Ocean Engineering and a consultant to the M.I.T. Museums. He was an honorary member of the Boston Marine Society and the Society of Naval Architects and Marine Engineers and the author of many books and articles on maritime history.

John W. Kilduff, 1896-1981

John W. Kilduff, '18, formerly vice-president and general manager of the Amesbury Metal Products Co., died in Clearwater, Fla., August 21; he was 85.

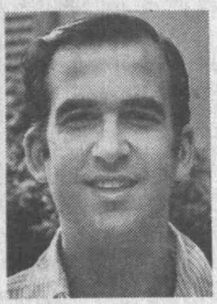
Active in alumni affairs, Mr. Kilduff had been president of his class since 1958, chairman of the Alumni Fund in Newburyport, Mass., and an active participant in M.I.T. capital fund programs during the last 20 years. He was recognized for a number of major engineering contributions, including the design of stainless steel facilities for experimental animals at the Jackson Laboratories, Bar Harbor, Maine.

Deceased

William W. Rawlinson, '08; November 14, 1979; 5643 Canterbury Dr., Columbus, Ohio.
Ralph W. Horne, '10; August 9, 1981; 14 Winn Terrace, Malden, Mass.
L. G. Fitzherbert, '11; July 4, 1981; 59 Hundreds Circle, Wellesley, Mass.
Francis E. Stern, '16; August 14, 1981; 45 Beverly Rd., West Hartford, Conn.
Chester E. Ames, '17; August 13, 1981; 1 Pond St. #10G, Winthrop, Mass.
John W. Kilduff, '18; August 21, 1981; 4574 Great Lakes Drive S, Clearwater, Fla.
Leslie H. Marshall, '18; November 26, 1980; 3560 Stuart Ct., Fort Meyers, Fla.
Willard A. Case, '21; August 7, 1981; 935 Rainbow Dr. NW, Route 7, Lancaster, Ohio.
William Wald, '21; June 28, 1981; 101 Monmouth St. #103, Brookline, Mass.
I. Robert Loss, '22; March 3, 1981; 2333 North Bay Rd., Miami, Fla.
George W. Bricker, '23; June 18, 1981; 216 Forest Beach Rd., South Chatham, Mass.
William S. Wise, '23; July 2, 1981; 37 Bishop Rd., W. Hartford, Conn.
Richard H. Starke, '24; June 1981, 69 Marlborough Dr., Vincentown, N.J.
Robert U. Berry, '27; August 12, 1981; 9392 Church Rd., Gross Ile, Mich.
Harold F. Haase, '27; January 30, 1981; 2253-A S Layton Blvd., Milwaukee, Wis.
Herman G. Daiker, '28; August 13, 1981; 977 Summer St., Bridgewater, Mass.
Edgar W. Pitt, '28; September 1, 1981; 2391 Areca Palm Rd., Boca Raton, Fla.
Everett F. Kelley, '29; June 21, 1981; 75 Fisk St., P.O. Box 1117, West Dennis, Mass.
Robert L. Barrett, '30; May 25, 1981; 913 Washington St., Dorchester, Mass.
Cecil G. Dunn, '30; August 12, 1981; 3608 East Monte Vista Dr., Tucson, Ariz.
Ralph W. Peters, '30; August 14, 1981; 16 Whitestone Ln., Rochester, N.Y.
Horst H. Orbanowski, '31; June 19, 1981; 10 Plow Ln., Greenwich, Conn.
William A. Baker, '34; September 8, 1981; P.O. Box 122, Hingham, Mass.
Guy F. Barnett, '34; July 15, 1981; 840 Meadowood Ln., Warminster, Penn.
S. Curtis Powell, '37; August 28, 1981; 2605 N. 36th St., #G-108, Phoenix, Ariz.
John S. Haponik, '38; July 4, 1981; 69 Brookside Rd., Braintree, Mass.
John B. Dwyer, '40; August 12, 1981; 338 Hedwig Rd., Houston, Tex.
Theodore J. Fabik, '41; August 7, 1981; P.O. Box 8725, Monterey, Calif.
Ernest Artz, '42; May 18, 1981; 1406 Cider Knoll Way, West Chester, Penn.
Walter R. Milliken, '46; June 15, 1980; c/o William Lambert, 4501 Poppe Pl., Camp Springs, Md.
John B. Beckwith, '58; July 1981; 152 Belridge Rd., Bristol, Conn.
Charles W. Cravens, '58; July 29, 1981; 227 Fontaine Circle, Lexington, Ky.
Alberto Jimenez, '68; May 17, 1981; Los Jazmines 275, Chosica, Peru.

Puzzle Corner
Allan J. Gottlieb

Red or Yellow Columbines?



Allan J. Gottlieb, '67, is associate research professor of mathematical sciences at the Courant Institute of Mathematical Sciences, New York University; he studied mathematics at M.I.T. and Brandeis. Send problems, solutions, and comments to him at the Courant Institute, New York University, 251 Mercer St., New York, N.Y., 10012.

Let me begin with responses from several readers.

As you may recall, earlier this year we had a plea from Larry Bell for suggestions of books containing mathematical puzzles. Smith Turner has recommended three: Steinhouse, *Mathematical Snapshots* (Oxford University Press, New York, 1960); Phillips, Shovelton, and Marshall, *Calibaos Problem Book* (T. de la Rue and Co., London, 1933); and Schuh (translation by Gobel), *The Masterbook of Mathematical Recreation* (Dover, New York).

Robert Cutler writes that he has studied the function C obtained by factoring a positive integer into primes, summing the primes, and iterating the procedure until a prime results. By definition $C(p) = p$ when p is a prime and $C(1) = 1$. [C(4) is undefined.] For example, the calculation that $C(98) = 5$ proceeds as follows:

$98 = 2 \cdot 7 \cdot 7$; $2 + 7 + 7 = 16$; $16 = 2 \cdot 2 \cdot 2 \cdot 2$; $2 + 2 + 2 + 2 = 8$; $8 = 2 \cdot 2 \cdot 2$; $2 + 2 + 2 = 6$; $6 = 2 \cdot 3$; $2 + 3 = 5$.

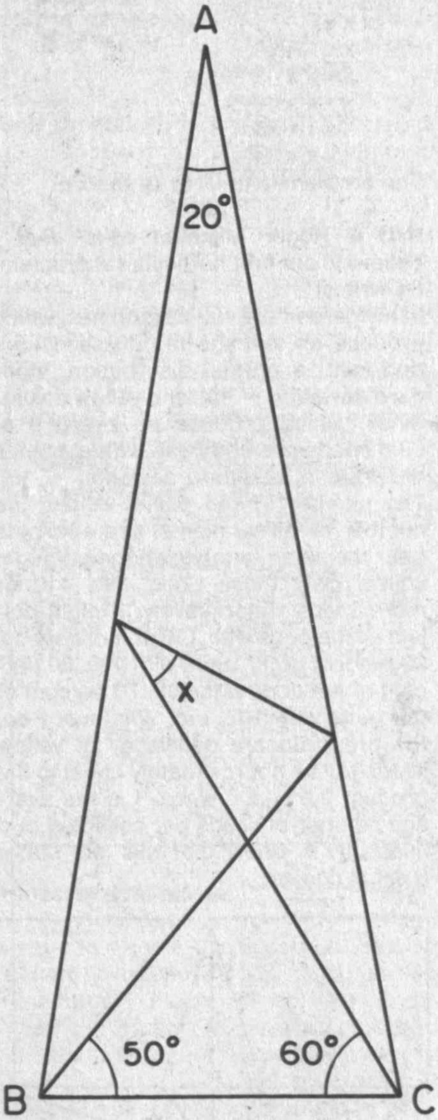
Mr. Cutler wonders whether C has been studied before. Can anyone help him?

Finally, to answer a question from John Ruttersford: I very rarely play bridge (perhaps 15 hands a year)—and not especially well (I finesse but don't squeeze).

Problems

N/D 1 For variety we begin this month with an Othello problem from Scott Byron: What is the shortest possible game of Othello?

N/D 2 Craig Murphy asks you to find angle x in the isosceles triangle ABC shown below (AB = AC). He demands that the solution use only plane geometry; in particular, he forbids trigonometry. However, he adds, "If you become sufficiently frustrated, you may use trigonometry to find x, since knowing the result may help point the direction in which to look for a geometrical solution."



N/D3 The following problem first appeared in a Calibron Products advertisement in *Technology Review* for June, 1939:

Ask a friend to write down *any* number B. Above B, write another number A, made up of all the digits in B *and any additional digit except O,* arranged in

any order. Subtract B from A. Ask your friend to tell you the final answer, C. For example,

A	65,835
B	5,653
C	60,182

You can find the unknown added digit (8 in the example) as follows: add together the digits of C, and if this result contains two or more digits, add these together in turn, and so on, until only one digit remains. This will be the extra digit that was added in forming A. Why? (In the example, $6 + 0 + 1 + 8 + 2 = 17$; $1 + 7 = 8$; and 8 was the added digit.

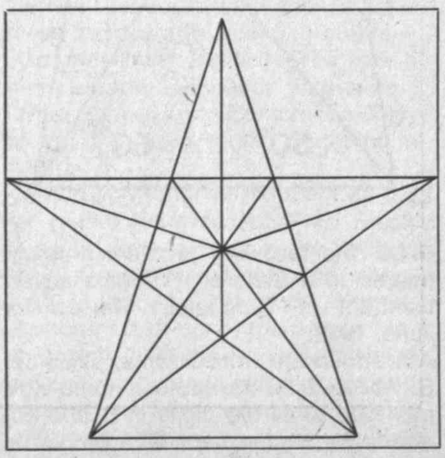
N/D 4 John Trifiletti has a square root problem with only one known digit:

```
          x x x x
  √x x x x x x x x
   x
   x x x
    x x
    x x x x
    x x x x
      x x x x x
      x x x 3 x
```

The problem is to fill in all the x's.

N/D 5 Roger Milkman asks what I believe is our first horticultural problem. He writes:

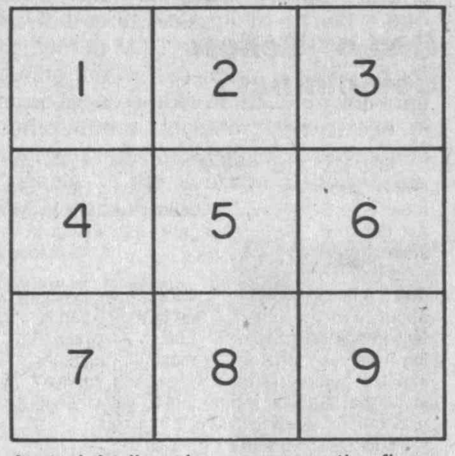
In my garden are red columbines, which produce an average of 100 seeds per pod (with a normal distribution, standard deviation = 10), and yellow columbines, which produce an average of 99.8 seeds per pod (also with a normal distribution, standard deviation = 10). The number of red plants equals the number of yellow plants, and all plants bear the same number of pods. I might collect only those pods with 110 or more seeds. Alternatively, I might collect all the pods with 110 or more seeds, 90 percent of the pods with 109, 80 percent of the pods with 108, 70 percent of the pods with 107, etc. Whatever I do, the proportionate deficiency of yellow seeds will be approximately equal to the product $0.01 \cdot 0.2 \cdot i$, where i is the average number of seeds per collected pod minus 99.9. Show that this last statement is correct.



Speed Department

N/D SD 1 Adam Becker wants to know how many triangles can be found in the figure at the bottom of column 1.

N/D SD 2 R. Steffens sent us the following counting problem.



A straight line drawn across the figure will traverse a subset of the nine squares, for example 1,2,3 or 1,4,7. How many of the possible subsets so determined include square 1?

Solutions

JUL 1 South to lead and make all seven remaining tricks:

North: ♠ J 8 6; ♥ A J 4; ♦ A; ♣ —

West: ♠ K; ♥ K 8; ♦ 9; ♣ K 8 6

East: ♠ 10 7 2; ♥ 9 6; ♦ 4; ♣ 9

South: ♠ A 9; ♥ Q 7; ♦ —; ♣ J 10 3

Unfortunately, we failed to specify the trump suit. But several readers, including W. Cuttler, interpreted that omission as part of the problem and deduced the answer. Mr. Cuttler writes:

The last time I submitted a solution to a bridge problem, back when you were a student at M.I.T., I was chided by one of your readers on the grounds that I had peeked at the East-West hands. To avoid that this time, let me say that I refrained from peeking until the problem was solved. However, in solving the problem, I assumed that the key cards in the opponents' hands were so located that the hand was makeable; otherwise the problem would not have been submitted. Although not mentioned, I also assumed that hearts were trumps. I could find no possible way for South to lead and take the seven remaining tricks with any other suit as trumps or in no-trumps. With the above as a preface, here is the solution:

1. South leads ♣ J. West must cover with ♣ K (obvious). North trumps with ♥ 4.
2. North leads ♦ A. South trumps with ♥ Q.
3. South leads ♥ 7 to North's ♥ A over West's ♥ K.
4. North draws remaining trumps. South discards ♣ 3.
5. North leads ♠ 6 to South's ♠ A.
6. South plays ♣ 10. North discards ♠ 8.
7. South leads ♠ 9 to North's good ♠ J.

Also solved by George Holderness, Mike Bercher, Doug Van Patter, Noland Poffenberger, Matthew Fountain, Richard Hess, Robert Garrels, Peter McCall, John Ruttersford, and the proposer, Emmet Duffy.

JUL 2 What is the smallest multiple of nine that has no odd digit, calculated in base 10? What is the answer if other bases are used? And how many ways are there of doing it?

The key to this puzzle is to recall the "casting out nines" rule. For example, Avi Ornstein writes: The digits in any multiple of 9 must add up to produce a number which is also a multiple of 9 (in base 10, that is). [This is "casting out nines."—Ed.] To have no odd digits, the sum must be even, so the digits must add up to a multiple of 18. The smallest number that meets these specifications is 288. If the problem were not limited to base 10, the smallest possible solution would be 22, in various bases. In base 8 this is equal to 18. If you choose to state that 9 does not exist in base 8, then you can use 22 in base 17, which is equal to 4 x 9, or 36, in base 10.

Also solved by Emmet Duffy, Edwin McMillan, Frank Carbin, Marion Weiss, Richard Hess, Matthew Fountain, Winthrop Leeds, Richard Kruger, Avi Ornstein, Howard Wagner, and Phillip Burnstein.

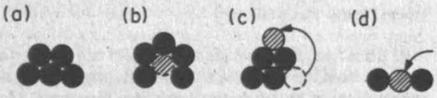
JUL 3 A falling person reaches a terminal velocity of about 55 m/sec. Entering feet first, one can survive falls into water at speeds of up to 34 m/sec. Starting from rest, what is the maximum distance one can fall before entering water, and survive? Assume that drag is proportional to velocity and that gravitational acceleration is 9.8 m/sec.

Michael Jung sent us the following solution:
Let the drag acceleration be $d = kv$. Since $55k = 9.8$, $k = 9.8/55$. Starting with $v' = 9.8 - kv$, we obtain $v' + kv = 9.8$
$v'\exp(kt) + kv\cdot\exp(kt) = 9.8\cdot\exp(kt)$
$[v\cdot\exp(kt)]' = 9.8\exp(kt)$
$v\cdot\exp(kt) = 9.8/k\cdot\exp(kt) + C = 55\exp(kt) + C$
$v = 55 + C\cdot\exp(-kt)$.
Since $v(O) = O$, $C = -55$. Thus
$d = \int v(t)dt = 55t - 55/k\cdot\exp(-kt) + C$.
Applying the boundary condition $d(O) = O$, we obtain
$d = 55\,(t - [1 - \exp(-kt)]/k)$.
Since the maximum velocity is 34, we see by plugging into the formula for v that the maximum velocity occurs at
$t = in(55/21)k$.
Finally, inserting this last value into the formula for d gives
$d = 55/9.8\,[55in(55/21) - 34] = 106.38$ m.

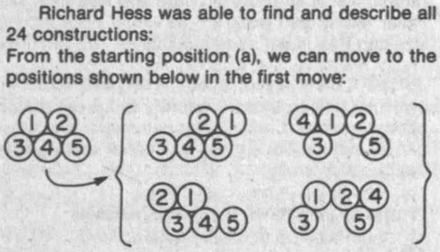
Also solved by Richard Hess, Matthew Fountain, Marion Weiss, John Prussing, Frank Carbin, Steve Feldman, Winthrop Leeds, Robert Slater, Richard Kruger, William Schoenfeld and the proposer, Eric Piehl.

JUL 4 Five coins, arranged as in (a) below, are to be shifted into arrangement (b), using *only four* accurate sliding moves [such as the move shown in (c)]. There is no restriction on the position of arrangement (b) relative to (a), but the new location of any coin moved must be fixed by *definite* contact with two other coins: *estimated* contacts [to form straight lines, as in (d)] are not allowed. Move only one coin at a time, without lifting. Our analysis of this old puzzle shows that there are no less than 24 straightforward solutions.

(a) (b) (c) (d)

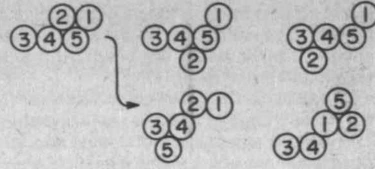


Richard Hess was able to find and describe all 24 constructions:
From the starting position (a), we can move to the positions shown below in the first move:

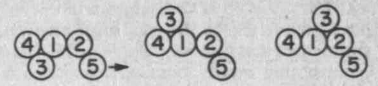


From the two basic positions created above (each with a multiplicity of two), we can move to the positions shown on the next page in the second move:

(X2)

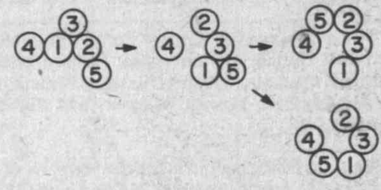


(X2)

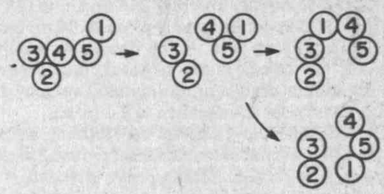


From the two basic positions created above (one with multiplicity 4 and one with multiplicity 8), we can move to the positions below in the third and fourth moves:

(X4)



(X8)



The two ways in each case to move from the third to the fourth position times the multiplicities of 4 and 8 give the 24 ways to reach the final position.

Also solved by Marion Weiss and Matthew Fountain.

JUL 5 What is the smallest square matrix in which can be written the names of 50 U.S. states, horizontally or vertically in crossword-puzzle fashion?

Matthew Fountain sent us the following 27 x 27 solution:

```
              W Y O M I N G     S O U T H D A K O T A
                  H               R                 L
    M I S S O U R I               E     F L O R I D A
    I             O           W   G                 B
    N                   N     E   O   N E B R A S K A
    N E W M E X I C O   E     S   N           R     M
    E     O       A     W     T     L O U I S I A N A
    S     N       L     Y     V               Z
    O     T     W I S C O N S I N     V E R M O N T
A   T E X A S     F     R     R               N
L   A     N       O     K     G   M I C H I G A N
A         A       R           I             E
S       H   P E N N S Y L V A N I A   C O L O R A D O
K A N S A S       I           I             R
A       W   M     A R K A N S A S     V I R G I N I A
  N E V A D A   N               O       L   I   O
C       I   S   E   M   N   N   U       L   A   R   R
O   W   I   S   W   I   E   O   T   O   I     U T A H
N   A       A   H   S   W   R   H   K   N       H   O
N   S   D   C   A   S   J   T   C   L   O   K   C   D
E   H   E   H   M A I N E   H   A   A   I   E   A   E
C   I   L   U   P   S   R   D   R   H   S   N   R   I
T   N   A   S   S   S   S   A   O   O       T   O   S
I   G   W   E   H   I   E   K   L   M   I   U   L   L
C   T   A   T   I   P   Y   O   I D A H O   C   I   A
U   O   R   T   R   P       T   N       W   K   N   N
T E N N E S S E E   I N D I A N A     M A R Y L A N D
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Also solved by Peter McCall, Richard Hess, and the proposer, Richard Fisher.

Better Late Than Never

JUL SD 1 Alan Faller notes that we did not require a straight hole, so one with side an equiangular (logarithmic) spiral satisfies the problem. However, Mr. Faller shows that such a hole would have infinite size and thus is not constructable.

JUL SD 2 Dan Grayson does not consider solutions involving infinite series "speedy" and proposes an alternate method. Alan Faller comments that most people include the mother and father when giving the size of a family.

Proposers' Solutions to Speed Problems

SD 1 79.
SD 2 27. Specifically, the following subsets: 1, 12, 123, 1236, 1256, 12569, 1258, 12589, 1259, 126, 14, 1456, 14569, 1458, 14589, 1459, 147, 1478, 148, 156, 1569, 158, 1589, 159, 214, 2147, 3214.

Secured landfills are designed specifically to contain hazardous wastes, and when operated properly should minimize contamination of the environment.

waste waters, decolorize liquids, control odors, and recover solvents. Activated carbon is obtained from coal, wood, coconut shells, and other organic materials, and is used in either granular or powdered form. The specific raw materials and manufacturing method determine the carbon's structure, adsorption characteristics, and regenerability. Regeneration is usually accomplished by heating the carbon particles until materials held in their pores desorb—a procedure that is expensive because of its high energy requirements. However, this thermal technique may one day be replaced by improved methods, such as critical solvent extraction, which uses milder temperatures and therefore is less costly.

The other common sorbent is resin. Resin has a lower adsorption capacity than activated carbon, but its chemical nature can be manipulated to make it highly selective. Also, resin regeneration does not require such high temperatures; thus, resin may be better than carbon when material recovery is desirable. In combination, the activated-carbon and resin adsorption systems could become widely used, as together they offer flexibility at an acceptable cost.

Solidification/Encapsulation. This is the process of deactivating and immobilizing toxic chemicals by incorporating them into the structure of a stable solid compound with high physical strength, minimal leachability, and (ideally) minimal cost. Although solidification/encapsulation is now used for a small fraction of hazardous wastes, it promises to become one of the most important disposal techniques.

Practically all processes for treating hazardous wastes produce some residue, and frequently that residue is also toxic. Therefore, solidification is usually the last treatment operation before waste streams are sent to a secured landfill for storage. Also, for concentrated heavy-metal solutions and hazardous wastes that cannot be incinerated or detoxified by other methods, solidification is the only environmentally sound method of preparing the wastes for storage.

There are four major kinds of solidification technologies: cement-based, lime-based, thermoplastic, and polymerization. Techniques using cement are most common because they are cheap and easiest to use. They are effective principally for inorganic wastes, especially those containing heavy-metal cations such as cadmium, chromium, copper, lead, mercury, and nickel. The alkalinity of the cement stabilizes the heavy metals in the form of hydroxides, much as did the ores from which the metals originated. Asbestos, metal filings, and other materials often present in waste streams add strength to the cement matrix, and companies generally use proprietary additives to make the cement even stronger. However, organic materials in the wastes generally weaken the cement.

A major advantage of cement-based techniques is that wastes need not be dried before processing. On the other hand, the resulting solid matrix is vulnerable to acid leaching and the freeze-thaw and wet-dry cycles of the environment. However, these problems can be overcome by burial beneath the frost line.

Lime-based techniques are similar to cement-based methods in principle and application. They are somewhat less expensive, but the solid matrix is weaker and thus more vulnerable to environmental changes.

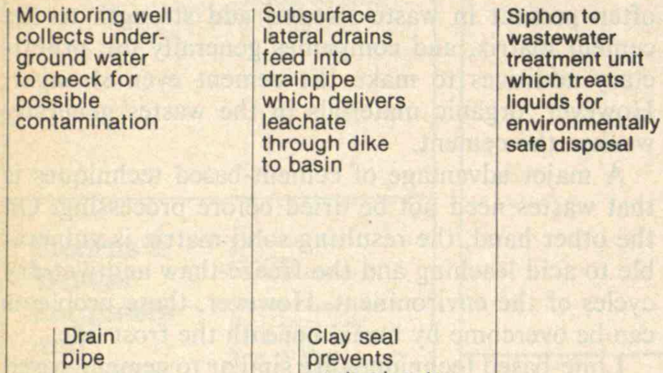
Thermoplastic techniques use bitumen, asphalt, and other materials that soften when heated, bind tightly to waste materials, and solidify when cooled. Wastes frequently must be dried before being mixed with the hot thermoplastic material. The principal advantage is that the binders immobilize waste materials very well, and the resulting solid structure allows minimal leaching, being very resistant to most aqueous solutions and acids. Thermoplastic techniques are thus especially suited to highly hazardous and concentrated wastes. However, the solid structure may be flammable and deteriorate if exposed to organic solvents. Another drawback is that thermoplastic processes have high material and operating costs.

In the polymerization method, a monomer is mixed with the wastes and allowed to polymerize, trapping the toxic materials in the resulting matrix. Because material requirements are lower, this process is less expensive than thermoplastic methods. The process also is applicable to both aqueous and nonaqueous hazardous-waste streams.

Many of the approaches used in solidifying hazardous industrial wastes are based on processes developed for the treatment of radioactive wastes. Those processes have been modified to take into account the larger volumes associated with toxic chemical wastes.

Secured Landfill. Secured landfills are sites for the ultimate disposal of liquid and solid wastes, mixtures, and residues from *all* waste-treatment operations. Such sites are designed specifically to contain hazardous wastes, and when operated properly should minimize contamination of the environment.

Past experiences with landfills have been dismal. Many landfills were created in marshlands, abandoned sand and gravel pits, and other sites that have



A secured landfill has a number of essential geological, hydrological, and geographical features. Past experiences with landfills have been dismal, with many sited where they could contaminate underground water. However, secured landfills offer the best method for disposal of many hazardous wastes and are the only viable method for most inorganics. (Diagram: Chemical Manufacturers Association)

hydraulic connections with underground water. Poor strategic planning also meant wastes were often transported great distances. Despite such a bad track record, secured landfills offer the best method for disposal of many hazardous wastes, and the only viable one for most inorganics.

Proper landfill design involves geological, hydrological, and geographical considerations (*see the figure above*). Of utmost importance is location in thick natural clay deposits where the hydraulic transport of leachate to an underground water source is unlikely. Ideally, wastes in the landfill will have been properly solidified, but drums or other containers can be used for storage of liquids and sludges. Individual clay-lined cells may also be required to ensure that incompatible wastes do not come in contact with one another. To ensure proper operation of the site, special techniques that prevent failures are required, as are quick repair methods to be used in an accident. The facility's operating procedure must also include scientific studies that assess the risk of system failure and the impacts of possible accidents on people and the environment.

Recent regulations set by EPA under the provisions of RCRA were designed, in part, to ensure safer construction, operation, and closure of landfills. For example, the regulations require collection, monitoring, and treatment of the leachate. And the owner or operator of a facility is required to provide for post-closure care of the landfill for 30 years or more, as determined on a case-by-case basis. One may argue that such a period of post-closure responsibility is impractical since the operating company may not exist for that long. Moreover, many heavy metals remain toxic forever, so perpetual monitoring should be required. The EPA is now considering establishing some form of national insurance plan to cover such extended monitoring programs.

Improving Our Options

To encourage proper handling of hazardous wastes, many research organizations and pioneering companies are trying to improve technological options. Some of their efforts are leading to novel ways of using standard techniques. For example, burning halogenated organic wastes at sea—on ships or unused oil rigs—has been shown to be both feasible and less expensive than standard land incineration because exhaust-gas treatment is not necessary.

But many techniques under development are quite different from old ones. Lockheed and EPA have developed a microwave plasma process for detoxification of pesticides and other toxic wastes. Rockwell International is using molten-salt combustion to attain complete and rapid destruction of many toxic organic wastes; molten sodium carbonate rapidly absorbs many toxic emissions from the system, making exhaust scrubbers unnecessary. The Department of Agriculture is developing a method for treating chlorinated hydrocarbon-bearing wastes by simultaneously bubbling oxygen through the wastes and irradiating them with ultraviolet light. This process apparently breaks the chlorine-carbon bonds, and the

Only with more basic research can we increase the fundamental knowledge needed to develop policies and technologies that provide maximum safety at reasonable cost.

remaining compounds can be biodegraded by soil microorganisms.

Several companies are developing organisms that thrive on certain hazardous materials. For instance, Hooker Chemical has commissioned Battelle-Columbus to engineer an organism that thrives on chlorinated aromatics, and Koppers has contracted with Genex to develop an organism that detoxifies coal-tar wastes. Battelle Pacific Northwest Laboratories will soon begin field tests of a technique for immobilizing buried toxic-metal wastes. An electric current is passed between electrodes placed in the ground around the wastes, melting the wastes, soil, and rocks into a solid. The vitrified material becomes compact, leaving a hole that can be filled in.

Other new techniques are designed not only to treat hazardous wastes but to recover energy and materials—an important combination as we try to adopt processing techniques that conserve our resources. For example, Chem-Trol Pollution Services has burned chlorinated hydrocarbon-bearing wastes together with conventional fuels in a cement kiln, accomplishing waste treatment while producing cement and saving energy.

Similarly, several U.S. utilities burn wastes in combination with fuel oil to run boilers and generate electricity. In Geisman, La., Borden Chemical Co. is building a French-designed incinerator that burns chlorinated hydrocarbon wastes; the system provides recovery of both hydrochloric acid and a significant fraction of the heat of combustion. The use of water hyacinths—fast-growing plants—for treatment of both industrial and municipal wastes is being explored by Exxon and through a joint effort by EPA, the state of California, and the city of San Diego. While water hyacinths cannot tolerate high salinity, they efficiently degrade many organic materials (especially municipal wastes) and remove heavy metals. The hyacinths can later be harvested and either used for animal feed, composted, or fed to a digester that produces methane to fuel the facility.

Industry and government have set up special programs to study another aspect of the hazardous-waste problem: how to identify specific substances that pose a threat to humans and the environment. In 1975 the chemical industry established the Chemical Industry Institute of Toxicology (CIIT) in Research Triangle Park, N.C., to conduct tests on commodity chemicals, develop toxicological methodologies, and provide postdoctoral training of toxicologists. Thirty-six companies now support the CIIT, which has already produced important results, most notably evidence of the carcinogenicity of formaldehyde. The federal government performs many activities relating to the testing of hazardous chemicals through its National Toxicology Program.

In addition to testing specific chemicals, these and other organizations are designing new tests that will prove simpler, cheaper, and more accurate than existing methods. CIIT has recently developed a test for carcinogenicity that uses animals instead of cell cultures, allowing for the effects of chemical processes in the animal's body. The National Institute of Environmental Health Sciences has published the results of a two-year study involving 12 nations; it shows that no single test can be used on all potentially carcinogenic compounds, but suggests a series of tests that may be effective. Such procedures will help identify the most threatening wastes and combinations, enabling us to set priorities in tackling waste problems.

In spite of all our past and present work, our fundamental understanding remains limited. We do not know the exact mechanisms by which hazardous compounds damage the human body and the environment, nor do we have the full scientific knowledge needed to design and operate optimal waste-treatment and disposal processes. Indeed, our achievements have mostly resulted from empirical methods. Only with considerable basic research can we increase the fundamental knowledge needed to develop policies and technologies for hazardous-waste management that are scientifically sound and that provide maximum safety at reasonable cost.

Further Reading

Doull, J., C. Klaassen, and M. Amdur, eds., *Casarett and Doull's Toxicology*. New York: Macmillan, 1980.

Holdgate, M.W., *A Perspective of Environmental Pollution*. Cambridge: Cambridge University Press, 1979.

Lippmann, M., and R.B. Schlesinger, *Chemical Contamination in the Human Environment*. New York: Oxford University Press, 1979.

Maugh, T.H. *Science*, May 25-June 22, 1979.

Noyes Data Corp., *Unit Operations for Treatment of Hazardous Industrial Wastes*. Park Ridge, N.J., 1978.

Pojasek, R.B., ed. *Toxic and Hazardous-Waste Disposal*. Ann Arbor: Ann Arbor Science, 1980.

Sax, N.I., *Dangerous Properties of Industrial Materials*. New York: Van Nostrand, 1979.

U.S. Environmental Protection Agency, *Disposal of Hazardous Wastes*. Report to Congress, EPA SW-115, 1974.

U.S. Environmental Protection Agency, *State Decision Maker's Guide for Hazardous-Waste Management*. EPA SW-612, 1977.

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The Federal-State Dilemma

by Ann Rappaport

HAVING the necessary treatment and disposal technologies available is one part of the complex equation for solving the hazardous-waste problem. Ensuring that the technology is appropriately used is the other. Although government has adequate legal authority to require sound waste management, as a practical matter that authority cannot be exercised without substantial public and private support.

Many firms and institutions have not internalized waste-treatment and disposal costs, so adoption of treatment methods may require new investment in equipment or services. While regulations requiring waste management are clearly beneficial to public health, the environment, and the waste-disposal industry, other sectors of the economy foresee dramatic increases in the cost of doing business and are therefore fighting for exemptions and exclusions from regulations.

As directed by the Resource Conservation and Recovery Act of 1976, in May of 1980 the U.S. Environmental Protection Agency (EPA) published a comprehensive regulatory program to set a national pace. States are encouraged to assume responsibility for regulating their own hazardous wastes and ensuring their proper management. After all, individual states are in a better position than the federal government to tailor programs and regulations to local patterns of hazardous-waste generation and hydrogeological features.

An issue now being resolved on a state-by-state basis is the extent to which states may develop programs that go beyond the federal model. These concerns are illustrated by two examples: the manifest system and the exemption level.

The Manifest System. This is often referred to as the heart of the "cradle-to-grave" hazardous-waste tracking process established by federal law. The manifest is a shipping document indicating the origin, destination, type, and volume of waste and containing certification from each party that the waste is properly packaged and accurately characterized. All wastes in transit from a waste generator to a waste-handling facility must be accompanied by a manifest, and the facility must return a signed copy to the generator showing that the material has been received.

EPA decided to require that it be notified only when a signed copy from the waste-handling facility had not been received by the generator within 45 days of shipment. This is referred to as an "exception-reporting" system because government is informed that a shipment is in transit only after the waste and/or its paperwork cannot be located.

States such as California, New York, Illinois, New Jersey, Pennsylvania, and Maryland have implemented "load-by-load" tracking systems in which the generator and the facility send copies of all manifests to the state. Such a load-by-load system enables the state to identify trends and enforcement problems, pinpoint industry education needs, ensure that unsound practices are quickly stopped, and augment its data base on waste transactions.

For example, individuals have sometimes inaccurately represented themselves to generators as being licensed to handle hazardous wastes. Under the federal system, a state must rely on annual reports and exception reports to identify a transfer to such an unlicensed party. Thus, a full year of disposal at an illegal facility can occur, with potentially serious consequences to public health and the environment. Under the load-by-load system, the state would receive a manifest indicating the transfer, and state staff could immediately provide a generator with a list of licensees and offer other assistance in interpreting regulations.

Opponents of the load-by-load tracking system argue that the paperwork is burdensome and that the federal system is adequate. Proponents of load-by-load tracking feel the paperwork burden is justified by benefits in protection, enforcement, and education.

The Exemption Level. States frequently have elected to be more stringent than the federal government in establishing exemption levels limiting the applicability of hazardous-waste regulations. Except for a few acutely toxic wastes, federal regulations provide that sources generating or accumulating less than 1,000 kilograms per month of hazardous waste need not comply with record-keeping, reporting, and handling requirements, and need not send their waste to an approved hazardous-waste disposal facility. This exemption level was based on the fact that 91 percent of hazardous-waste generators nationwide produce less than 1,000 kilograms per month, contributing only about 1 percent of the total hazardous waste produced each year. A closer look, however, reveals that national statistics may not be a sound basis for state policy.

For example, in the Northeast there are many small companies in the metal-plating, metal-finishing, paint and coating, and other industries that produce small amounts of hazardous waste. Consequently, concern has been growing about the potential effects of a large number of small generators depositing hazardous wastes in municipal landfills, particularly in areas where poorly protected aquifers are a major source of drinking water.

States Take Different Route

Such concern has prompted Rhode Island to establish a zero exemption, and New Hampshire, Vermont, Maine, and New York to set the exemption limits at 100 kilograms per month. Massachusetts' comprehensive regulatory program is in the draft stage, but a study of available data indicates that at 1,000 kilograms per month, perhaps 25 percent of the waste generated in the state would escape regulation, and at 100 kilograms per month approximately 5 to 7 percent would escape regulation. Obviously, exclusion levels must be practical. As the exemption level goes down, the potential for environmental protection increases, but eventually the limits of program administration are reached. There is clearly a need for compromise between exemption limits and

INITIALS: MICHAEL G. COBB

effective law enforcement in attempting to maintain acceptable public health and environmental protection.

While states are allowed to develop and enforce regulatory programs more stringent than federal programs, they often encounter formidable barriers—particularly lack of resources and influence. Most state governments have traditionally had a harder time than private industry and the federal government in attracting and keeping qualified staff and in obtaining sufficient resources for research and program administration. Each state also needs to attract new businesses and keep old ones, and competition among the states is stiff. Compounding these difficulties are new initiatives to limit government spending and a growing sentiment that government regulation stifles economic expansion and contributes to inflation. These factors can adversely affect both the timing and quality of state efforts to ensure sound waste-handling practices quickly enough to prevent future problems.

Also, industry groups that win exemption from federal regulations will usually oppose state efforts to establish different exemptions or requirements. States seeking to protect a local phenomenon, such as a vulnerable aquifer used for drinking-water supplies, could face real problems if challenged, since few states can match industry resources. States must then look to the concerned public and innovative industries to support strong regulatory programs. Firms that make early investments in source reduction and sound waste handling may rely on government efforts to prompt their competitors into making comparable expenditures.

The Public's View

Developing sound and effective programs for hazardous-waste management is complicated by an often emotional public reaction to real and perceived threats. Without scientific data, environmental and health consequences of particular situations are often speculative. As a result, communities adversely affected by chemical contamination often push for conservative remedial actions. In Plymouth County, Mass., for example, a variety of toxic chemicals, apparently leaching from a municipal landfill, reached wells providing drinking water to homes. The levels of contaminants detected were well below the "Suggested No Adverse Response Levels" (SNARLs) established by EPA, based on the limited available epidemiological and toxicological data.

Local decision makers therefore had two choices: they could do nothing, based on the rationale that contaminant levels are far below SNARLs; or they could appropriate $775,000 to provide affected homes with water from an uncontaminated town well. The town chose to pay for the alternative water supply.

Risk-averse behavior of this type is to be expected at the local level. However, when risk aversion is extrapolated to the state or national level, it suggests a scale of corrective actions with a dollar value that far exceeds government's ability to pay. In fact, federal "Superfund" monies allotted for site cleanup are expected to be so meager in many states that only the most serious problems will be tackled. For example, the current list of problems in Massachusetts includes contamination by polychlorinated biphenyls (PCBs, a family of persistent synthetic compounds) of an estuary and major fishing port, possible thallium poisoning of residents in a rural town, and several sites where stockpiled wastes threaten major public sources of drinking water. Thus, the Plymouth County situation and others like it are not serious contenders for federal or state funds. Massachusetts and other industrialized states with many contamination problems clearly lack the resources to provide zero-risk remedies that the public expects. Industries performing their own cleanup operations face the same problem.

Cost Cuts Cause Criticism

Recognizing serious fiscal constraints, government increasingly looks for ways to minimize costs in providing acceptable solutions to site contamination problems. Sometimes this means taking actions that critics see as government capitulation to industry pressure. For example, in cases where responsible parties can be identified and the threat to public health is not imminent, agencies may negotiate compliance and schedules for remedial action designed to keep the violator solvent and ensure corporate responsibility for cleanup or containment. But where an agency considers the threat to public health imminent, it may take immediate measures to stop polluting activities, running the risk that taxpayers will have to pay for corrective action if the violator declares bankruptcy.

Hazardous-waste regulations now contain details on performance standards, operating procedures, security measures, contingency plans, and a host of other provisions designed to protect public health and the environment. New statutes and regulations also require establishment of trust funds or other mechanisms to prevent taxpayers from assuming the financial burdens for unsuccessful or mismanaged waste-disposal ventures. But skeptics still question the adequacy of regulations and the ability of government or any other group to enforce their provisions.

To overcome such skepticism and community resistance to the siting of new facilities, regulators are encouraging widespread public participation in all aspects of the program: in developing the regulations, in monitoring facilties' compliance with performance standards, and in carefully selecting sites for waste-treatment facilities. These methods have yet to be put to a suitable test on the national level, but community participation in the development of regulations at the state level has already yielded positive results. □

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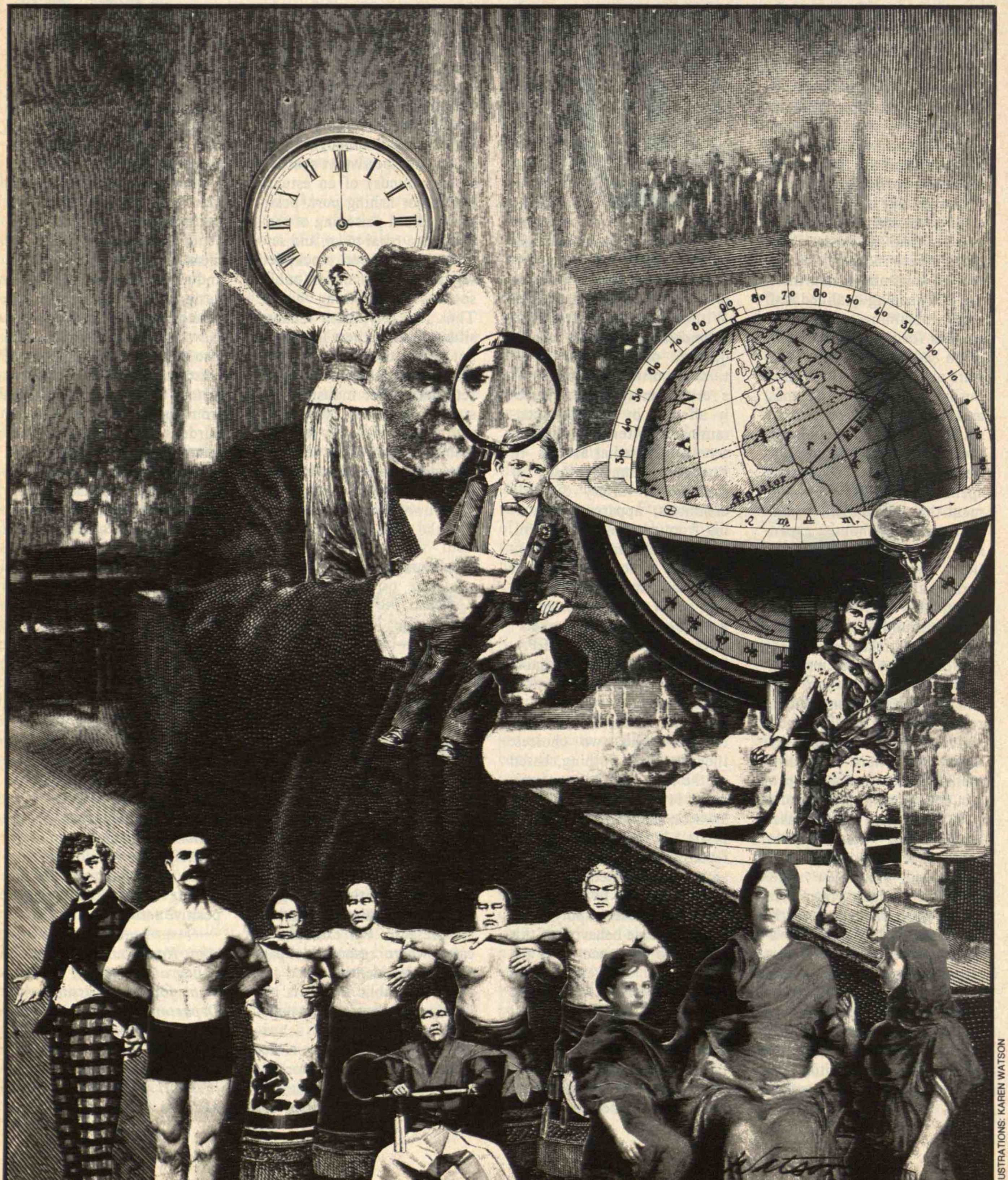


ILLUSTRATIONS: KAREN WATSON

In Pursuit of the Public Health

by Brian MacMahon

The complexity of social systems and the heterogeneity of the human species have made the epidemiologist's task a difficult and lonely one.

THE fundamental objective of epidemiology—to understand the relationship of a population's health to its environment—has remained the same since Hippocrates' dictum of 2,400 years ago:

Whoever wishes to investigate medicine properly should thus: in the first place to consider the seasons of year, and what effects each of them produces. Then the winds, the hot and cold, especially such as are common to all countries, and then such as are peculiar to each locality. In the same manner, when one comes into a city to which he is a stranger, he should consider the situation, how it lies as to the winds and the rising of the sun; for its influence is not the same whether it lies to the north or the south, to the rising or the setting sun. One should consider most attentively the waters which inhabitants use, whether they be marshy and soft, or hard and running from elevated rocky situations, and then if saltish and unfit for cooking; and the ground, whether it be naked and deficient in water, or wooded and well watered, and whether it lies in a hollow, confined situation, or is elevated and cold; and the mode in which the inhabitants live, and what are their pursuits, whether they are fond of drinking and eating to excess, and given to indolence, or are fond of exercise and labor.

In light of such a clear statement from such an influential teacher, it is remarkable that for more than 2,000 years virtually nothing was discovered about the specific characteristics of environments that led to disease. The British epidemiologist Major Greenwood, writing some 40 years ago, attributed this to the fact that the operative word in Hippocrates' statement is *consider*—not *count*. But Greenwood believed that however full of insight an investigator's "considerings" may be, they are unlikely to form a firm foundation for future generations of investigators if they are not supported by observations recorded in quantitative terms.

The first serious attempt to count health-related events was undertaken in the middle of the seventeenth century by John Graunt, a gentleman of London and a founding fellow of the Royal Philosophical Society. Graunt chanced on the weekly "Bills of Mortality" published by the parish clerks of the City of London episodically from about 1600, principally to monitor the comings and goings of the plague. He collected as many of the bills as he could find and analyzed them to show that more males were born than females, and that males died younger, though females were more frequently sick. He also found that mortality was high among infants, that there were seasonal fluctuations in mortality, that more people died of the plague than were so recorded (as with influenza today) and, more parochially, that "not one in two thousand are murdered in London" and that "The Gowt stands at a stay" but "the Scurvie encreases." Graunt was the first to attempt two basic statistical procedures—the estimation of the population of a large city (London) and the construction of a

Humans choose a broad range of dosages of a variety of potential toxic substances.

table showing the age distribution of the population. Even more important, he demonstrated "the uniformity and predictability of . . . biological phenomena taken in the mass"—the cornerstone of biostatistics and quantitative epidemiology.

A Grand Experiment

In the middle of the nineteenth century, epidemiology received methodologic inspiration from the work of John Snow, a London anesthesiologist. Snow is known for his dogged documentation of the case-to-case transmission of cholera, particularly his linking of several hundred cases of the disease in an epidemic of 1845 to a single contaminated water pump. However, his broader contribution stemmed from his refusal to limit himself to previously recorded information. He did not ask, as did Graunt, "What use can I make of this information?" but "What information do I need to solve this problem?" Having observed a geographical association between the risk of cholera and the water source of several districts, he perceived a way of testing the hypothesis that the water source was responsible for the spread of the disease:

The intermixing of the water supply of the Southward and Vauxhall Company with that of the Lambeth Company, over an extensive part of London, admitted of the subject being sifted in such a way as to yield the most incontrovertible proof on one side or the other. In the subdistricts . . . supplied by both Companies, the mixing of the supply is of the most intimate kind. The pipes of each Company go down all the streets, and into nearly all the courts and alleys. A few houses are supplied by one Company and a few by the other, according to the decision of the owner or occupier at that time when the Water Companies were in active competition. In many cases a single house has a supply different from that on either side. Each company supplies both rich and poor, both large houses and small; there is no difference either in the condition of occupation of the persons receiving the water of the different Companies. Now it must be evident that, if the diminution of cholera, in the districts partly supplied with the improved water, depended on this supply, the houses receiving it would be the houses enjoying the whole benefit of the diminution of the malady, whilst the houses supplied with the water from the Battersea Fields would suffer the same mortality as they would if the improved supply did not exist at all . . . It is obvious that no experiment could have been devised which would more thoroughly test the effect of water supply on the progress of cholera than this, which circumstances placed before the observer.

The experiment, too, was on the grandest scale. No fewer than 300,000 people of both sexes, of every age and occupation, and of every rank and station, from gentlefolks down to the very poor, were divided into two groups without their choice, and in most cases without their knowledge; one group being supplied with water containing the sewage of London, and, amongst it, whatever might have come from the cholera patients, the other having water quite free from such impurity.

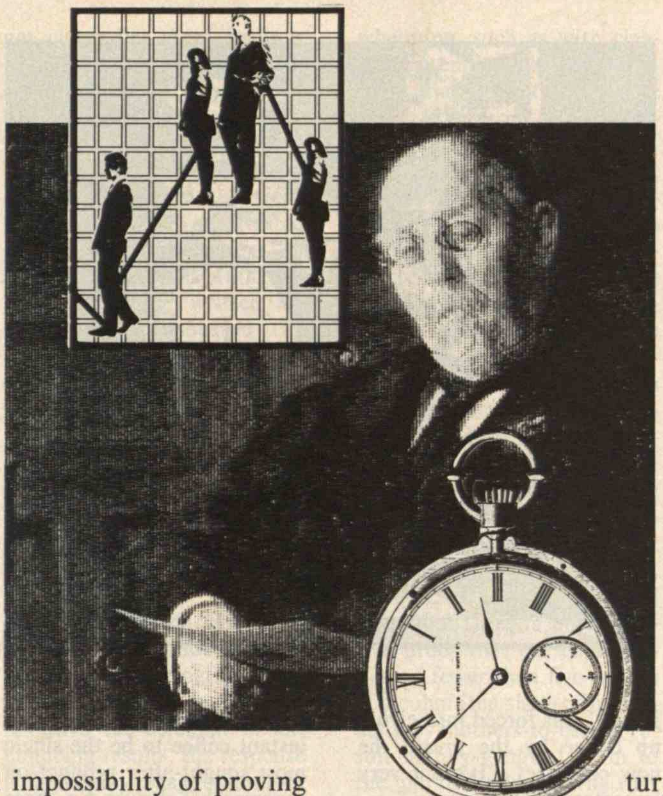
To turn this grand experiment to account, all that was required was to learn the supply of water to each individual house where a fatal attack of cholera might occur.

This Snow proceeded to do, demonstrating unequivocally the insalubrious nature of the sewage-water mixture distributed by the Southward and Vauxhall Company. Much of the epidemiology since Snow has consisted of attempts to identify and exploit other "natural experiments" to elucidate the etiology of human disease.

A Human Subject

A little more than a century after Snow, epidemiology is experiencing another revival. The stimuli for this include a change in the patterns of the major diseases affecting technologically developed nations—with a corresponding need to understand the causes of the new diseases—and recognition of the fact that epidemiological studies have an enviable record of contributing to our understanding of the relationship of the environment to human health. While the laboratory produced the means for control of infectious disease, epidemiology first told the microscopists where to look and what to look for. There are few exceptions to the generalization that the agents known to cause cancer in people have first been identified as carcinogens in studies of humans rather than animals. Laboratory studies of other species have yielded an understanding of the mechanisms and principles of carcinogenesis and teratogenesis (the propagation of congenital defects), but knowledge of the specific agents responsible for human disease has come predominantly from studies of humans.

In addition to asking "What are the causes of this



disease?" epidemiologists today raise questions such as: "Given that substance *X* occurs in the human environment, what, if anything, is it doing to human health?" While the first type of question is difficult to answer, the second is even more perplexing. When the focus of investigation is a disease, one at least knows that the disease exists and that it must have causes. If we cannot discern these causes, it is only because of our own limitations. However, when investigating an exposure, one does not know whether a problem exists and may be faced with the statistical impossibility of proving the absence of an association. Furthermore, we may be searching for a rare effect against a background of similar effects resulting from other causes.

If we know or suspect that a given substance causes ill health at some level of exposure, we need to discern what its effects are, if any, at the lowest level to which humans are or may be exposed. The problems of measuring the effects of low-level exposures and distinguishing them from "no-effect" levels are, of course, vastly greater than those of identifying common outcomes of heavier exposures (*see "Lead Exposure and Human Health" by Herbert L. Needleman, March/April 1980, p. 38*).

The strengths and limitations of epidemiology in these contexts stem from the two principal characteristics of the science—it is concerned with studies of humans and it is predominantly observational. One obvious advantage to dealing with humans is that the necessity of extrapolating inferences across species is avoided. A less widely recognized advantage is that people expose themselves to hazardous substances with abandon. For financial reasons, the typical toxicological experiment uses the smallest possible number of animals and the largest nonlethal doses of toxin to maximize the chances of achieving an effect. Useful inferences from such studies therefore involve extrapolation not only across species but from enormously high to very low doses.

Humans, on the other hand, are not only readily available in very large numbers but also house, feed, and clean themselves at no expense to the investigator. They also choose a broad range of dosages of a variety of potentially toxic substances. Consider the cigarette habit, to which hundreds of millions of persons have exposed themselves at levels ranging from almost zero (for those exposed only through smoking by others) to the addict's three or four cigarettes per waking hour, and the 2 million or more deaths from lung cancer in the last half-century in this country alone. Consider that fewer than half of all American women pass through menopause without either having their uterus surgically removed or being liberally dosed with hormones known to increase cancer risk in animals, or both. Consider the implications of more than 50 million women worldwide regularly taking contraceptive hormones that essentially cut off the function of their own ovaries. Such facts must make the tinkerers in the animal laboratory green with envy.

Monitoring the effects of these human behaviors has permitted the identification of innumerable hazards never suspected from laboratory experiments—the most likely cause of the lung cancer epidemic, the high risk of uterine cancer associated with estrogen use, the variety of cancers associated with exposure to ionizing radiation, the role of rubella and certain therapeutic drugs in the development of congenital defects, and the literally hundreds of causes of ill health attributable to exposure in the workplace.

The oral contraceptive story is instructive. Work with experimental animals led experimenters to believe that use of these compounds might be associated with increases in the risk of cancer, particularly breast cancer. No such increases have yet been observed. On the other hand, substantially increased risk of death from cardiovascular disease associated with these contraceptives is now well established, particularly for

Trouble Brewing

LAST March millions of Americans were shaken when Dr. Brian MacMahon and a team of four other physician-researchers at the Harvard Medical School suggested that coffee drinkers might stand a significantly higher risk of contracting cancer of the pancreas—the fourth most common variety and responsible for 20,000 deaths annually. Dr. MacMahon is careful to caution that his findings, originally published in the *New England Journal of Medicine*, are preliminary. "I don't think the evidence is strong enough to make a general recommendation," he says, "but it is more likely than not that there is some correlation."

Despite this caveat, the media responded to Dr. MacMahon's report with a vengeance. He was quoted in major newspapers and magazines, and was even pressed on a popular talk show to admit to millions of television viewers that, yes, he had given up his morning java: "I was forced into giving up coffee by the press," he now confesses. "It's not very important to me anyway."

But coffee *is* very important to a large segment of the American economy. A recent survey showed one brand of instant coffee to be the single most sought-after product on supermarket shelves. So, three days after Dr. MacMahon's findings were announced, the American Council on Science and Health (ACSH) was "interpreting" the report for the lay public.

The ACSH defines itself as an "independent educational association promoting scientifically balanced evaluations of chemicals, the environment, and human health." However, according to Terry Smith, ACSH assistant director, 93 percent of the organization's $700,000 annual budget comes from industry—either directly or through industry-sponsored "private foundations." The ACSH conducts no original research but instead hires free-lance "investigators" to search the available literature and write summary reports forwarded to a board of experts paid to review them. Once cleared for accuracy, copies of the reports and condensed "lay" versions in booklet form are circulated.

Almost immediately after the MacMahon report was released, the ACSH held a press conference to report on *its*

women over 35 who have other risk factors for cardiovascular disease. Discovery of this totally unexpected risk clearly demonstrates the danger of any surveillance or regulatory system that depends solely on inferences from animal experiments. Were our ultimate concern the health of guinea pigs rather than humans, it would be unwise to proscribe the use of oral contraceptives by guinea pigs on the basis of the cardiovascular effects on humans. Guinea pigs do not get cardiovascular disease.

Some Drawbacks

The most serious limitations of epidemiology stem from its observational nature. Some epidemiology is experimental—that is, it involves the deliberate manipulation of a suspected cause to measure the change in a supposed effect. In such experiments, subjects can be randomly selected and measured in standard ways, but with human subjects, variables are limited to circumstances or things presumed to be beneficial—a therapy or a preventive measure such as a vaccine or water flouridation.

However, most epidemiology is not experimental but depends on inadvertent observations of ill health and exposures distributed capriciously throughout the population. It is rare that an observed association between a particular disease and a particular exposure in any one study can be said with confidence to indicate a causal connection. Nearly always, the observation must be repeated under different circumstances using different methods until enough information has been assembled to make alternative explanations unlikely.

When a single study is convincing, it is usually because the disease involved is uncommon and the experience shared by the afflicted people unusual. For example, the associations of vinyl chloride with angiosarcoma of the liver, of exposure of a

study of the health effects of caffeine. "In the past several years a number of unfounded or exaggerated reports on caffeine's harmful effects have been widely published," ACSH's booklet says. "Closer examination of studies that link caffeine consumption with five different diseases show that cigarette smoking is a more important factor than caffeine." It is difficult if not impossible to isolate the absolute effects of caffeine, the report continued, because so many people who consume caffeinated products also smoke. At the press conference, an ACSH representative suggested that Dr. MacMahon's study did not control adequately for cigarette smoking, despite the paper's careful detailing of such controls.

The MacMahon report stated specifically that it is not caffeine but one or more of coffee's thousand or so other volatile organic chemicals that seems to pose a cancer threat. ACSH says that its report did not contradict these findings because its research focused on caffeine, not coffee. However, the ACSH booklet is illustrated with pictures of coffee cans, coffeemakers, and coffee houses, and the word "coffee" is often substituted for "caffeine" in the text. In addition, while the 100-page "position paper" written for professionals discussed the deleterious effects of caffeine consumption on the digestive, central nervous, and cardiovascular systems, the lay version skipped over these details because, in Mr. Smith's words, "The public is most concerned with birth defects and cancer, so we decided to focus on these."

The MacMahon case illustrates the frustration inherent in the epidemiologist's task. No matter how cautious or tentative the scientist in announcing results, the response is inevitably exaggeration in the press followed by dismissal by special-interest groups. When the evidence is overwhelming, such as with cigarettes, epidemiological findings may eventually have some effect on public attitudes and behavior despite industry lobbying. But when the evidence is less than categorical, the common procedure is to assign the suspect substance to the lengthening list of "naughty niceties" that—given the hazards inherent in twentieth-century existence—often seem to be well worth the risk. An extreme extension of this attitude is exemplified by the ACSH's latest report. While recommending that pregnant women who "choose to drink" alcohol cut down to two drinks per day, the ACSH adds the cheerful news that there is no conclusive proof that the consumption of fewer than five ounces of alcohol (ten shots of liquor) daily by mothers-to-be will result in physiological harm to the child. While it's true that no scientific consensus on this issue has been struck, it is also true that few physicians would advise pregnant women to maintain a six-pack-of-beer-a-day habit. The ACSH's motivation in printing and circulating such a statement is questionable.

Certainly no single report or finding is sufficient to either damn or exonerate a product. In the case of coffee, Dr. MacMahon says he hopes that researchers in some other part of the country will run another study with the a priori hypothesis that coffee may increase the risk of pancreatic cancer. Since his group had "no idea" what factors might affect the risk of pancreatic cancer, they designed their study to look at a number of different factors. "We had no clues to the disease's cause or what could affect it," he says, "so this was a kind of fishing expedition." It is hoped that outside pressure and "expert reports" by industry-sponsored "think tanks" will not reduce the status of any future studies to that of mere fish tales.—*E.R.S.* □

fetus *in utero* to diethylstilbestrol (DES) with vaginal cancer in young women, of maternal rubella with cataracts and deafness, and of thalidomide with a set of previously extremely rare malformations of the limbs were accepted as causal almost immediately.

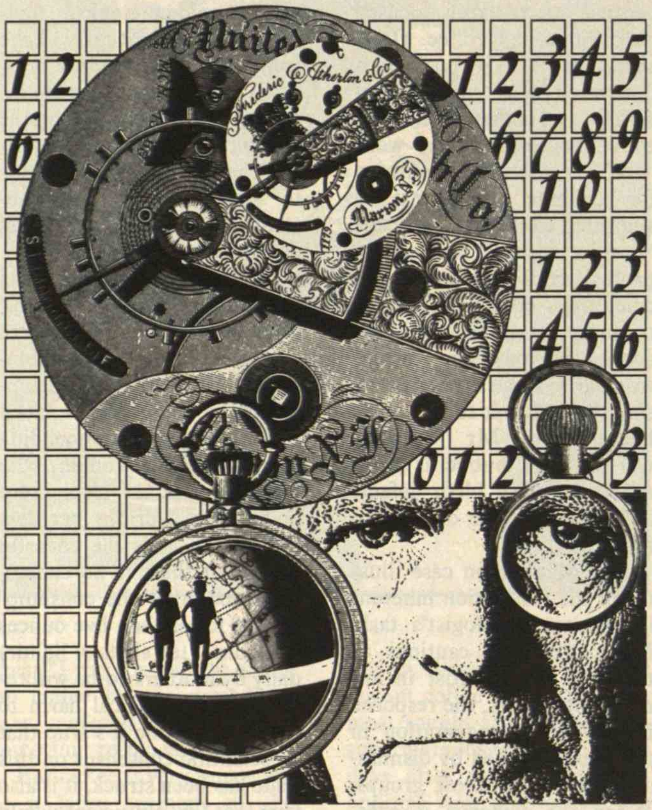
Much more difficult is the evaluation of increases of a fairly common disease in the absence of an obvious cause, such as when the incidence of a disease fluctuates against a background of "natural" incidence that itself fluctuates with time, geography, and socioeconomic status. Thus, the cigarette-lung cancer association was observed in more than 50 studies before the surgeon general saw fit to announce that cigarette smoking *may* be dangerous to health. Knowing that heavy cigarette smoking is associated with a 40-fold increase in lung cancer rates but that smoking habits vary considerably with age, sex, socioeconomic status, occupation, and other factors, we must be cautious in interpreting small increases in lung cancer rates in a particular occupation or other population subgroup. Some small difference between the smoking habits of that subgroup and the general population could result in a substantial difference in lung cancer rates. The same is true for other common disorders—such as fetal death—that have multiple causes that, again, vary with time, geography, socioeconomic status, and other characteristics.

Another frustration in epidemiological studies is that the lifetime of the subject often approximates that of the investigator. This becomes a serious problem when diseases develop only after periods of time that represent substantial fractions of an individual's lifetime. In these cases the experimentalist may be able to turn to a species with a shorter life span and, with luck, a speeded-up disease-induction time. The epidemiologist, by contrast, may be forced either to capitalize on past records or to join a study that has already existed for several decades.

Limitations specific to epidemiological data stem primarily from our lack of knowledge of the distribu-

The most serious limitations of epidemiology stem from its observational nature.

tion in the population of other factors that affect the frequency of diseases. Epidemiological studies may be misinterpreted as indicating lack of effect on health of a particular exposure because it is occurring too infrequently to be detected in a study of the given size, because the population was not studied at an appropriate interval after the exposure (so that the effects had already occurred and disappeared or had not yet occurred), or because the particular study involved a subpopulation not susceptible to the exposure.



These limitations are not only of great practical significance; they may also be insuperable. For example, if one defines as "meaningful" *any* effect, then one can never assemble a study group large enough to declare that there is *no* effect. If one assumes that the latency period between exposure and the appearance of health effects is 50 years, it may not be possible to study the association at all. If one decides that a substance must be regulated down to a level that would be safe for the most susceptible members of the population, one may never be able to identify that level since the susceptible individuals may be too few to study.

Not all these limitations are likely to apply to all studies—or even to any one study. So, as with the interpretation of positive associations, the accumulation of a series of negative studies using different populations and different methods may lead to an overall pattern that must be taken seriously in, for example, the regulatory process. Unfortunately, investigators are reluctant to expend their efforts and resources in studies they judge likely to be negative.

Not all the limitations of epidemiology are intrinsic. Researchers are constrained by a lack of resources and personnel and a general dearth of understanding of the purposes and uses of epidemiology. The present lack of trained epidemiologists—to which many government and private agencies will attest—has historical roots. Until the last decade, the great majority of persons working in epidemiology were physicians. Since epidemiology rarely involves the treatment of ill persons, it is not surprising that recruits from medical schools have never amounted to more than a trickle. That trickle sufficed to keep the discipline alive but not to meet current demands for the study of environmental health, the evaluation of medical services, and the investigation of toxic substances. However, the deficit is now being reduced by training programs that give investigators the necessary background in human biology and medicine as well as quantitative methods.

Resource shortages are not primarily financial but largely involve the difficulty of linking various records relating to the same individual. This country has superb files of death certificates giving basic demographic characteristics of the decedent and the certifying physician's notion of the cause of death. In 1979 the National Center for Health Statistics established a central National Death Index to facilitate the identification of deaths among any population subgroup. The lack of such an index limited previous work, and it will be some years before this one has accumulated enough data to be of maximum value. Retroactive indexing, though tremendously valuable, would be very expensive and seems unlikely to be undertaken in the near future.

Social Security files, which contain a lifetime record of employment and current "vital status" (living or dead) for most individuals, are seriously underutilized for research purposes. While their use for linking occupational exposures and mortality is increasing, this resource could be more effectively and widely used.

At least partially responsible for the slow progress in the development of records for epidemiolgical purposes—and indeed for some setbacks—is the fact that such records can impinge on the rights of privacy and

confidentiality of personal and medical information. There is little problem in situations in which individuals can be asked whether their records can be utilized. The difficulty comes when such permission is required for *any* use of individual records—as, for example, when very large samples are required or when individuals are no longer available to give their permission. The Privacy Protection Study Commission, established under the Privacy Act of 1974, has published recommendations and guidelines for use of medical records in research that, if implemented, would assure the continued availability of such records under procedural safeguards that protect confidentiality. Implementation of these recommendations would be a considerable step in the development of resources for epidemiological and other health research, but so far no appropriate legislation has been passed.

The range of human exposure to potential agents of disease in the environment is enormous. It is unfortunate that only a small proportion of this experience is observed, recorded, and analyzed to build our knowledge of the relationship between environment and health. With the availability of computers to record, store, and process information on an unprecedented scale, and the widespread recognition of the potential benefits of epidemiological research, an enlightened attitude toward the use of personal records for research should provide information of practical value to our own and future generations.

Further Reading

Graunt, J., *Natural and Political Observations Made Upon the Bills of Mortality* (1665). W.F. Willcox, ed. Baltimore: Johns Hopkins Press, 1939.

Greenwood, M., *Epidemics and Crowd Diseases: An Introduction to the Study of Epidemiology*. New York: Macmillan, 1935.

Hippocrates, *On Airs, Waters, and Places*. Translated and republished in *Medical Classics* 3 (1938):19-42.

Privacy Protection Study Commission. *Personal Privacy in an Information Society*. Washington, D.C.: U.S. Government Printing Office, 1977.

Snow, J., *On the Mode of Communication of Cholera* (1855). New York: Commonwealth Fund, 1936. Reproduced in *Snow on Cholera* New York: Hafner, 1965.

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The Politics of Preventive Health

by Donald Kennedy

This article was adapted from a speech originally presented by Dr. Kennedy at Stanford University.

MEDICAL progress has produced some remarkable changes in the state of our health and the ways scientists approach it. Today the postindustrial nations confront a variety of diseases that could fairly be called the new social diseases. Like the infectious diseases that preoccupied our forebears one or two hundred years ago, these are diseases of the environment, but we have not yet had a John Snow or a Percival Potts to show us in just what way they result from environmental factors. They are mainly diseases of age—diseases to which we have become subject as other infectious diseases were cured either by public-health measures of the nineteenth century or the curative medical technology that began in the early 1930s. Surviving these two major waves of scientific advance are cancer, cardiovascular disease, and a few others.

It is increasingly clear that a disease stems, at least in part, from lifestyle as well as the environment. Interesting methods of dealing with disease include a new interest in nutrition, an abiding mania for exercise, and a variety of voluntary measures that may well significantly influence health in this country.

But other risks are not so easily addressed by individual effort—those that result from the way we live as a society. This is the rationale for providing regulatory protection as one element of our national health strategy, and it is also the source of controversy.

Political Thresholds

I think two basic public attitudes fuel the debate over legislative controls on the public health. The first is a peculiarly American attachment to the technological fix—we are accustomed to purchasing scientific solutions to problems. "I think we should go to the moon," says a president, and soon enough we go. "I think we should cure polio," says someone else, and polio is cured. I don't know how many presidents have announced that we ought to cure cancer; the most recent to do so announced a "war" on it exactly a decade ago and appropriated $100 million for that purpose. Although some people were cautious, many Americans were persuaded that, as usual, victory would follow investment.

But the victory has not yet materialized, and public disillusionment with the research enterprise is significant enough to label the so-called war against cancer a kind of biomedical Vietnam. The more resources we expend, the more we seem to need. And the more tightly we think we have encircled the enemy, the more certain it appears to be upon us. So the American public is finally told that in fact we have met the enemy and it is us. Rather than paying for a technological fix, what we really have to do is give up cigarettes, diet soft drinks, and possibly even grilled hamburgers.

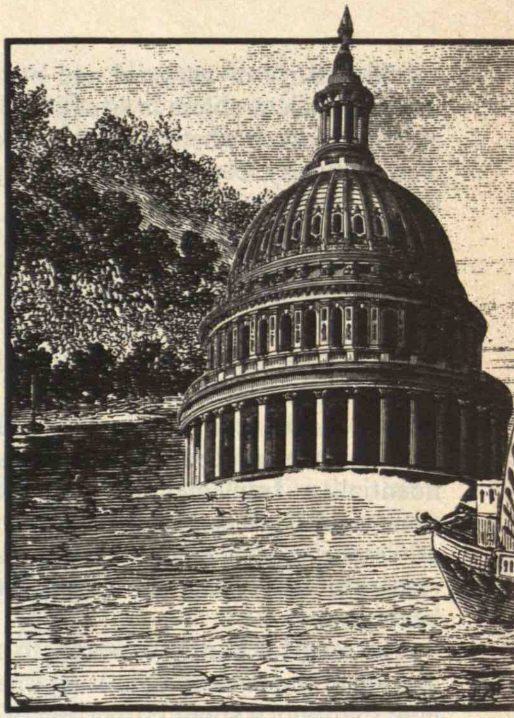
The second reason for the controversy goes much deeper. It has to do with a set of attitudes that have evolved as an important part of our country's heritage concerning the permissible degree of state intervention in private behavior. For example, medical intervention in the form of public immunization is justified by a version of the social contract, in which the state accepts some individual risk to prevent significant collective harm. The Supreme Court affirmed this requirement in the first decade of this century and few have cared to challenge it since.

In another case, a number of states have passed laws in the past decade requiring that drivers of motorcycles wear helmets. The usual justification is that substantial public resources are invested in the health of citizens and that participants in risky acts consume more than their share of these resources. But how much must the state invest to purchase control over individual behavior? It is not an easy system to gain command over. For example, federal requirements for devices that would prevent automobile ignition systems from working unless seat belts are buckled were quickly overturned by Congress.

Finally, what about state action to compel morning calisthenics or abstinence from cigarettes? After all, if state intervention in risky behaviors can be justified, a case for state encouragement of health-promoting behaviors could certainly be made. However, it is clear that there are certain limits beyond which state intervention is politically unacceptable to a majority of Americans. The political threshold may be located in the vicinity of motorcycle helmets, but it surely lies far short of compulsory morning calisthenics.

The Detection-Assessment Gap

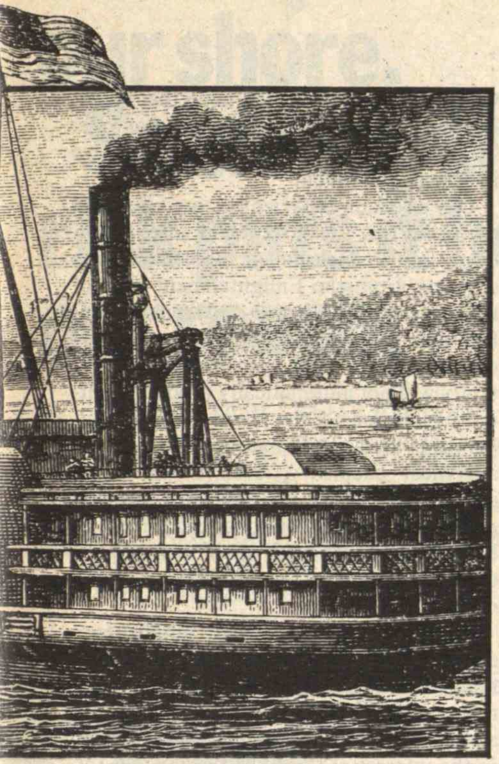
There was a time when the assessment and management of risk was a relatively straightforward matter. In the mid-nineteenth century, the Steamboat Inspection



Service was put in place to ensure that river steamboats did not accidentally explode. History does not record the existence of a Committee of 100 for Steamboat Freedom of Choice, dedicated to the promise of adventure between Memphis and New Orleans. One can even suppose that the manufacturers of the steamboat boilers and the proprietors of the steamboat lines thought it good that passengers had no reason to believe their trip was likely to terminate somewhere along the river, causing them to miss all kinds of connections with the not unlikely exception of that with their maker.

I yearn for those days because the hazards with which modern health and safety regulatory agencies must deal are so much harder to remedy, observe, or even define. Consider the latency of cancer and cardiovascular disease—with a decade, two decades, three decades between cause and effect, between exposure and disease. Consider the chemical environment that constitutes a significant fraction of the risk for those diseases, an environment remarkable for its diversity, its newness, and its extent.

The revolution in synthetic organic chemistry began around 1930. World production of synthetic organic chemicals has grown about tenfold since and now exceeds 150 billion pounds per year. Under the Toxic Substances Control Act, Congress gave the Environmental Protection Agency



(EPA) the task of counting the synthetic chemicals then in commercial use in the United States. Although the EPA thought it would complete the task in a couple of years, three and a half years later they are at 70,000 and still counting. When they get through that inventory, they can begin to apply the provisions of the act to the thousand or so new chemicals that come on line each year.

We have become very good at using some aspects of the scientific method for detecting those substances that are or may be risky. Whereas in the late 1950s we could detect substances in parts per million through conventional spectroscopy, in the 1960s we moved to parts per billion with the first mass-spectroscopy and chromatographic techniques, and to parts per trillion as better cleanup procedures and high-resolution mass spectroscopy and radioimmunoassay have come into wider use. So we can find almost anything we are readily determined to find, but this rate of progress contrasts alarmingly (at least to those of us in the regulatory business) with the lack of progress in the sciences of assessment—of epidemiology and toxicology.

To measure human hazard scientifically, you should be able to look at human populations and their environment and determine what the risk was, yet that is extraordinarily difficult to do. We have done it in a few cases where human populations have been heavily exposed, but in other cases we have to analyze exposure retrospectively, a statistical nightmare. I have yet to find an epidemiological study of this type that could not be converted into a scientific/legal donnybrook; experts could provide testimony on both sides of the question. The methods are simply subject to too much doubt and are too insensitive to be conclusive.

Also, collecting enough cases to provide a statistically reliable result at the levels of risk we are interested in often requires more cases than are at hand. For example, the largest epidemiological study available to evaluate the risk of artificial sweetener use in bladder cancer involved half the cases of bladder cancer in Canada over a five-year period, yet it was a hundredfold too insensitive for regulatory purposes. This means we must turn to the science of toxicology.

Toxicology has not been among the more progressive and lively disciplines in this country. It has been virtually disowned by its parent sciences, pharmacology and biochemistry, perhaps because it seems too applied. It confronts public skepticism—indeed, one might say it invites public disbelief—because of two stretches of reasoning that many members of the public find themselves unable to make. One is from rats to people. I urge any of you familiar with taxonomic distance to try and persuade the average citizen that it isn't all that far from him or her to a laboratory rat.

The second problem is that of the dose-response relationship. People simply cannot understand that in a large number of cases, multiplying the concentration of a chemical tenfold increases the sensitivity of a test tenfold because it simply moves one along a linear dose-response curve that has been shown to have the appropriate shape and constancy. That logic, though scientifically impeccable, is impossible to make politically convincing. So a scientific discipline that is intellectually quite respectable, although slow, confronts intractable public skepticism.

False Precision

We are terribly good, then, at finding small amounts of something we think may be dangerous, but we are terribly bad at whether it is in fact dangerous, and even worse at estimating how dangerous it might be. This is a prescription for political difficulty. An example is the dreadful piece of legislation known as the Delaney Clause. This part of the Food, Drug, and Cosmetic Act says that no food additive shall be deemed safe if it has been shown by appropriate experiment in humans or laboratory animals to cause cancer—period. Although it has never resulted in the successful banning of a compound you have ever heard of, the Delaney Clause draws a great deal of ire because it seems to be arbitrary and incapable of scientific revision. The latter charge I think is true, because the Delaney Clause really says that if *any* amount of a substance is likely to contribute to an increase in the incidence of a particular cancer, *no* amount of it is acceptable.

The Delaney Clause must be made more flexible before it shatters—there is no reason to make the law appear discouraging to scientific progress. The law should say that the finding of carcinogenicity creates a rebuttable presumption that a compound is not safe and should not be allowed into the food supply. That would give the interested manufacturer the incentive to either show that some particular aspect of the animal test is not appropriate for that compound, or to prove positively that there is a safe level. The existing law offers no such encouragement.

I think it is unappreciated, even by many scientists, that statements about risk are far from absolute. Suppose that the FDA is measuring the clinical benefit of a drug, or that it is assessing the risk of a potential carcinogenic food additive. It has a population of experimental animals or people, and it has a control population of matched animals or people. One group is fed whatever is being tested and the other group gets a good pretense that it is receiving the same thing. The people who examine the results don't know which have arisen from experimental and which from control procedures. Such "double-blind" experimentation is a marvelously simple idea and central to the design of every important experiment in this field. Sometimes the results are very clear. More often the excess of effects in the experimental group is marginal, and evaluators have to decide statistically whether it is due to chance or to the variable being scrutinized.

Biologists have accepted a convention that if there is no more than a one-in-twenty chance that the result is *not* due to the experimental variable, then the result is significant. But only when pressed to give full details does a biologist usually bother to point out that a set of confidence limits has been arbitrarily chosen. That kind of consideration was critical in half a dozen regulatory controversies in which I was involved at the FDA. We did not lack pre-

cision here, but that did not save us from criticism. After all, there is nothing magic about one in twenty or any other number we use to establish the significance of a result.

The scientific measures one can make of a toxic chemical and the risks associated with it are limited to its quantitative occurrence in the environment, the extent to which people are exposed to it, and the degree of its toxicity to those people. Many people believe that federal agencies have excessively complicated laws dealing with risk, and that if regulatory decisions were based simply on quantitatively ascertainable features, the system would be simple and workable. A committee on food safety policy organized by the National Academy of Sciences/Institute of Medicine after the saccharin affair described the present statutory categorization of food and food additives as "confusing, cumbersome, and not always related to risks." Not even the most ardent defenders of present health regulatory policy can say this complaint isn't true. But having been presented with the truth, where does one go?

Risk and the Political Process

I don't find myself in sympathy with the opinion that the food safety laws are undesirable or irrational or wrong simply because they're insufficiently related to measured risk. The level of risk is important and should be measured carefully. But other considerations often supervene in policy determinations, and these usually involve questions of social justice, the distribution of risks in relation to benefits, and the question of whether these risks are voluntary. These are important areas in which we cannot count on science to provide decisive yes-or-no answers. Yet there is often a tendency, particularly on the part of people outside science—especially members of Congress—to nurture the hope that somehow science can give definitive answers. The people who make our laws may believe in science too much.

Our affection for scientific precision and the belief that it can somehow solve everything is an anachronism, descended, one suspects, from the Enlightenment view of the universe as clockwork and from the Jeffersonian concept of the machinery of government. More relief from scientific uncertainty will not automatically produce political conclusions. Even if we could do animal tests as easily and accurately as we do analytical chemistry, even if we could assess human risk to the third decimal place, even if we could measure medical benefits of drugs with great precision, I think that most of our difficulties would remain.

There is genuine public ambivalence about risk in this country—not about how much risk there is, but about how much risk we want. Our citizens are uncertain about how much government intervention in the interest of their health they will tolerate, and they are also uncertain about how many other things—new inventions, creature comforts, old habits, progress—they are prepared to sacrifice to become safer. One does not resolve such doubts merely by stating the risks more precisely. They can be settled only through the political process, which takes into account the public view of such issues and then changes the law to accord with that view.

The true significance of saccharin, and indeed of nearly every such controversy, is that no matter how much attention appeared to be paid to the validity of the scientific tests, no one really cared exactly how strong a carcinogen saccharin was. They were much more interested in whether the warning was adequate to enable people to understand the risks, in whether people who understood the risks should be allowed to take them, and in questions such as what constitutes adequate warning and how juvenile diabetics could get diet soda.

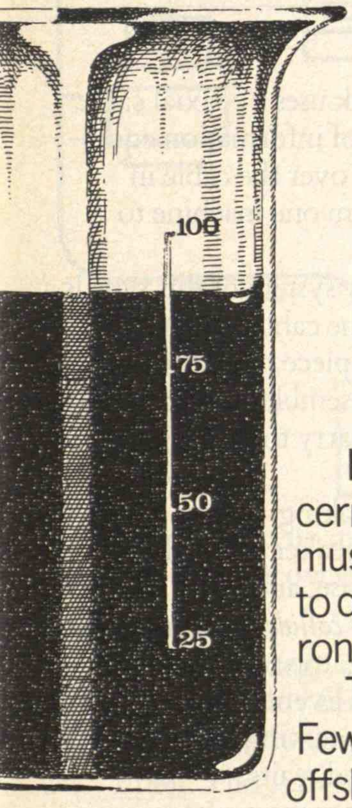
So our society is engaged in a public convulsion about the appropriate government stance in these matters, and I suspect that we will soon see a resolution. Science will help clarify the discussion, but it will not dominate it, for the great unresolved issues are not scientific but political. ☐

Donald Kennedy, president of Stanford University, was commissioner of the Food and Drug Administration from 1977 to 1979.

The promise of oil lies just beyond our shore. Some say the risk puts it beyond our reach.

There may be more than 20 billion barrels of oil still to be discovered beneath our offshore waters. And, along with it, possibly 100 trillion cubic feet of natural gas.

Today, technology gives us the potential of tapping these vast reserves.



But every concerned American must demand answers to questions about environmental safety.

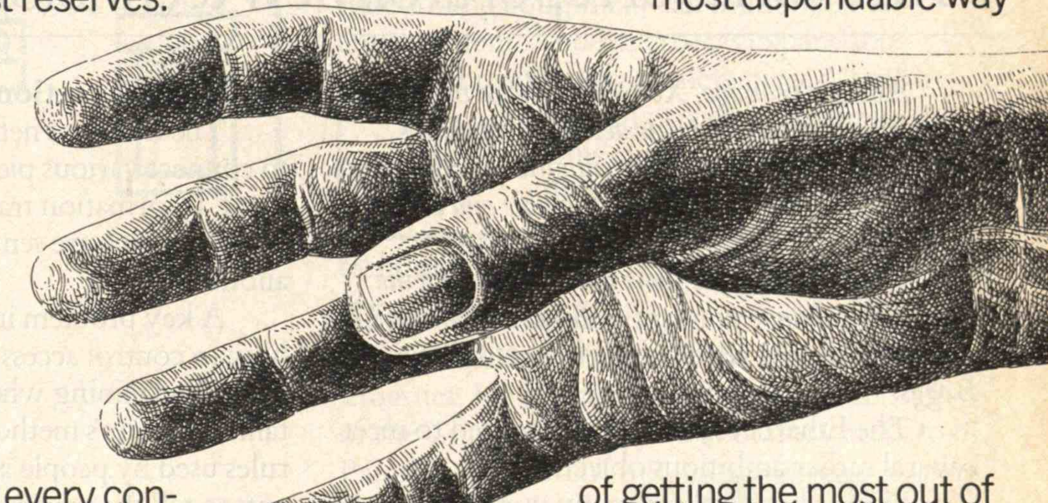
The facts are these: Few of the 21,000 current offshore wells have caused environmental problems.

And technology is further reducing the risk. This includes pumping techniques and blowout preventers that automatically shut down wells at the first sign of an emergency, sealing the well against fluid leakage.

What's more, commercial and sport fishing actually improves around oil platforms. They provide underwater areas where marine life can flourish.

Offshore oil and gas now provide about 10 percent of our daily energy needs. With only 2 percent of the country's one billion acres of potential offshore oil now leased, there is clearly much oil to be explored for under the sea.

Through our ARCO Oil and Gas Company, we're working to develop the safest, most dependable way



of getting the most out of the oil America has to offer.

Atlantic Richfield and thousands of Americans who have invested with us believe that exploring undersea is important in reducing our dependence on foreign oil.

And that's something we can't afford to ignore.

There are no easy answers.

ARCO

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THE LEADING EDGE

#1 in a series of reports on new technology from Xerox

About a year ago, Xerox introduced the Ethernet network—a pioneering new development that makes it possible to link different office machines into a single network that's reliable, flexible and easily expandable.

The following are some notes explaining the technological underpinnings of this development. They are contributed by Xerox research scientist David Boggs.

The Ethernet system was designed to meet several rather ambitious objectives.

First, it had to allow many users within a given organization to access the same data. Next, it had to allow the organization the economies that come from resource sharing; that is, if several people could share the same information processing equipment, it would cut down on the amount and expense of hardware needed. In addition, the resulting network had to be flexible; users had to be able to change components easily so the network could grow smoothly as new capability was needed. Finally, it had to have maximum reliability—a system based on the notion of shared information would look pretty silly if users couldn't get at the information because the network was broken.

Collision Detection

The Ethernet network uses a coaxial cable to connect various pieces of information equipment. Information travels over the cable in packets which are sent from one machine to another.

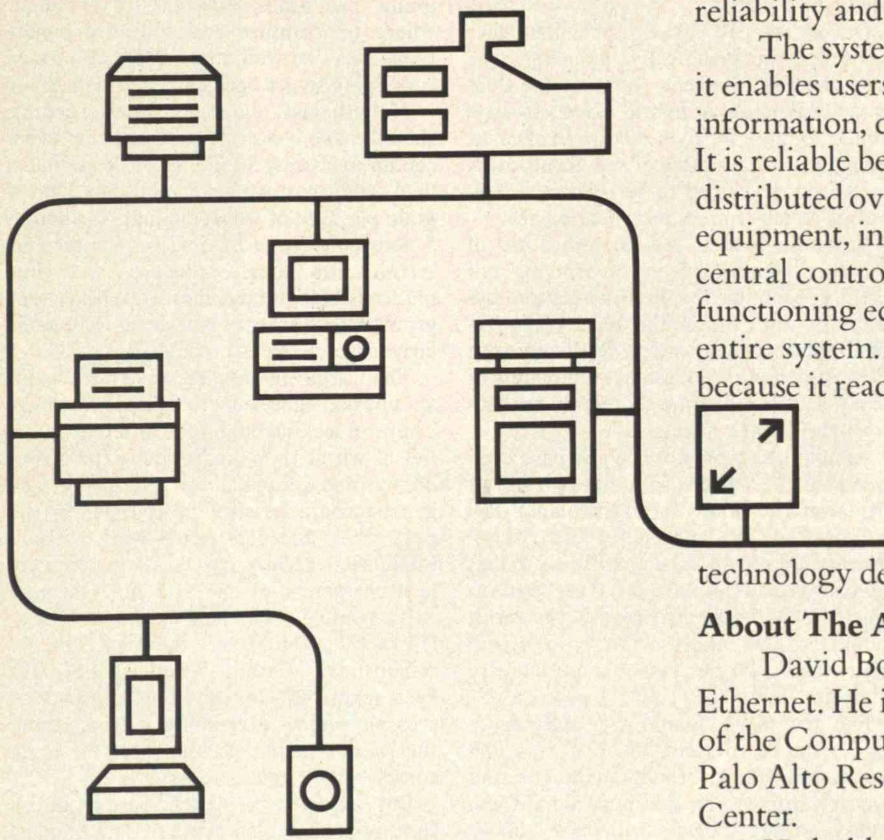
A key problem in any system of this type is how to control access to the cable: what are the rules determining when a piece of equipment can talk? Ethernet's method resembles the unwritten rules used by people at a party to decide who gets to tell the next story.

While someone is speaking, everyone else waits. When the current speaker stops, those who want to say something pause, and then launch into their speeches. If they *collide* with each other (hear someone else talking, too), they all stop and wait to start up again. Eventually one pauses the shortest time and starts talking so soon that everyone else hears him and waits.

When a piece of equipment wants to use the Ethernet cable, it listens first to hear if any other station is talking. When it hears silence on the cable, the station starts talking, but it also listens. If it hears other stations sending too, it stops, as do the other stations. Then it waits a

random amount of time, on the order of microseconds, and tries again. The more times a station collides, the longer, on the average, it waits before trying again.

In the technical literature, this technique is called carrier-sense multiple-access with collision detection. It is a modification of a method developed by researchers at the University of Hawaii and further refined by my colleague Dr. Robert Metcalfe. As long as the interval during which stations elbow each other for control of the cable is short relative to the interval during which the winner uses the cable, it is very efficient. Just as important, it requires no central



control—there is no distinguished station to break or become overloaded.

The System

With the foregoing problems solved, Ethernet was ready for introduction. It consists of a few relatively simple components:

Ether. This is the cable referred to earlier. Since it consists of just copper and plastic, its reliability is high and its cost is low.

Transceivers. These are small boxes that insert and extract bits of information as they pass by on the cable.

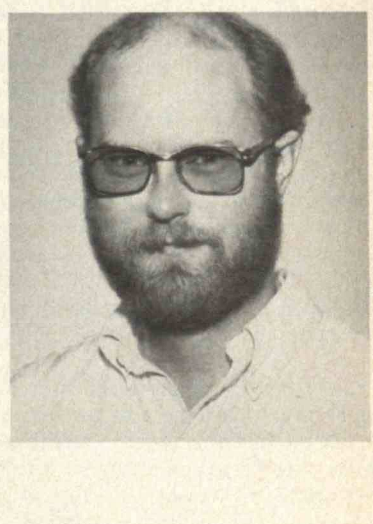
Controllers. These are large scale integrated circuit chips which enable all sorts of equipment, from communicating typewriters to mainframe computers, regardless of the manufacturer, to connect to the Ethernet.

The resulting system is not only fast (transmitting millions of bits of information per second), it's essentially modular in design. It's largely because of this modularity that Ethernet succeeds in meeting its objectives of economy, reliability and expandability.

The system is economical simply because it enables users to share both equipment and information, cutting down on hardware costs. It is reliable because control of the system is distributed over many pieces of communicating equipment, instead of being vested in a single central controller where a single piece of malfunctioning equipment can immobilize an entire system. And Ethernet is expandable because it readily accepts new pieces of information processing equipment. This enables an organization to plug in new machines gradually, as its needs dictate, or as technology develops new and better ones.

About The Author

David Boggs is one of the inventors of Ethernet. He is a member of the research staff of the Computer Science Laboratory at Xerox's Palo Alto Research Center.



He holds a Bachelor's degree in Electrical Engineering from Princeton University and a Master's degree from Stanford University, where he is currently pursuing a Ph.D.

XEROX

Myers/Continued from p. 9

expense of plowing and sowing could offer very large savings—the crop would come up by itself year after year, just like grass. In the United States alone, the amount of diesel fuel saved would be at least two and a quarter gallons per acre per year, or some $300 million.

However, a number of experts assert that perennial cereals do not yield as much as annuals. Whereas annuals tend to direct most of their vigor into their seeds, perennials divert part of it into their roots and hence tend to feature lower grain productivity.

Perennial corn was discovered at elevations between 7,000 and 10,000 feet. Its cool mountainous habitats are often damp and occasionally snowy, offering the prospect of growing cross-bred corn in wet soils beyond the survival capacities of conventional corn and expanding the cultivation range by as much as one-tenth. Even if yields in these marginal environments averaged only half those of more hospitable areas, the additional output could be worth at least $1 billion per year.

According to preliminary investigations by Dr. Lowell R. Nault of the Ohio Agricultural Research and Development Center, the Mexican variety is immune or tolerant to at least four of eight major virus and microplasm diseases. These now cause a 1 percent loss in the world's yearly corn harvests, worth well over $50 billion, meaning that added resistance would be worth $500 million a year. The perennial strain may also supply genes resistant to sundry insects, nematodes, fungi, and bacteria, resulting in even higher savings. The wild germ plasm could also supply hybrid vigor or other advantageous characteristics with sizable economic benefits.

What can be done to safeguard wild genetic reservoirs such as the one in a remote forest of Mexico? The revenues of seed companies that sell genetically improved corn seed could be taxed. This money could be used to subsidize those Mexican farmers, or farmers elsewhere, required to abstain from digging up patches of land with wild corn. Or, farmers could be encouraged through subsidies to continue to farm with traditional genetic varieties—"primitive cultivars," many on the verge of extinction—even though the genetically unique native corn might be only one-third as productive.

The seed companies taxed would undoubtedly pass on the cost to consumers, but the costs of a major crop failure would similarly be passed on as higher prices for corn products. Measures parallel in spirit and principle to this proposal already exist: the United States has supplied appreciable financial assistance to Mexico to keep hoof-and-mouth disease far south of the Rio Grande, safeguarding the U.S. livestock industry.

Although some observers may consider such subsidies a pie-in-the-sky notion, the day may be coming when we find that, as citizens of the global village, there is not much difference between being idealistic and realistic. □

Norman Myers, Ph.D., is a conservationist living in Nairobi, Kenya, and a senior associate of the World Wildlife Fund. His latest book is The Sinking Ark.

Cooke/Continued from p. 9

using this approach. But wheat breeders have not been able to take advantage of true hybrid vigor.

During the past 30 years scientists have succeeded in genetically inducing true male sterility in wheat—opening the door to the production of hybrid wheats in ways similar to those for hybrid corn. In essence, female plants incapable of self-fertilization have been developed to be used as recipients of pollen from other wheat plants.

But also needed was identification of "restorer" genes capable of bringing full fertility back to the first-generation hybrids. In other words, the male-sterile (female) plants must, when fertilized with selected pollen, yield abundant amounts of seed that will grow into the highly productive hybrid wheat plants.

Although these restorer genes have been found, it has been a complex task to maneuver them into the right plants. Researchers now have developed wheat varieties that are reliably male-sterile, as well as promising varieties that carry the restorer genes. When these are crossed, the result should be new wheat plants with hybrid vigor—and a 20 percent or more increase in yield.

The new plants should also carry genes for resistance to stem and leaf rust and Hessian fly attack, drought tolerance, and winter hardiness. In addition, since these high-yielding hybrids will carry more grains per head of wheat, the heads will be heavier and more apt to cause long stems to bend over—to "lodge"—in the field before they can be harvested. Therefore, dwarf and semidwarf varieties are being bred to grow stiffer stems and resist lodging. Such dwarfing genes were of great importance in developing the Mexican wheat varieties.

Beating the Competition

For a commercial seed company, of course, there's always the problem of competition. In addition to the large companies, the U.S. Department of Agriculture has scientists engaged in research on more and better wheat and several major universities have aggressive wheat research projects.

For example, the Cargill researchers note that commercial breeders were recently set to offer some promising hybrid wheats when the introduction of a high-yielding variety, not a hybrid, by government scientists in Texas forced a change in plans. The magic 20 percent increase in yield had disappeared when compared to the new variety's yield. Any introduction narrowing that gap means commercial breeders must return to their laboratories and try for more.

The Cargill scientists believe they can soon achieve a 20 percent boost in yield and stay that far ahead of new introductions expected from Department of Agriculture laboratories and universities. Although the average farmer can usually produce about 20 grains per head of wheat, according to David Johnston, a Cargill geneticist, "In the greenhouse we can get as many as 70 grains per head. However, in the field where temperature and moisture conditions aren't so well controlled, the farmer isn't going to get optimal performance."

Nonetheless, he says crossbreeding should make it possible to bring that average up to at least 30 grains per head under field conditions. An increase of only 1 extra grain per head of wheat amounts to about a 5 percent increase in yield for the farmer. And it's also thought to be possible to dramatically increase the number of heads that grow on each wheat plant, leading to similarly large increases in yield.

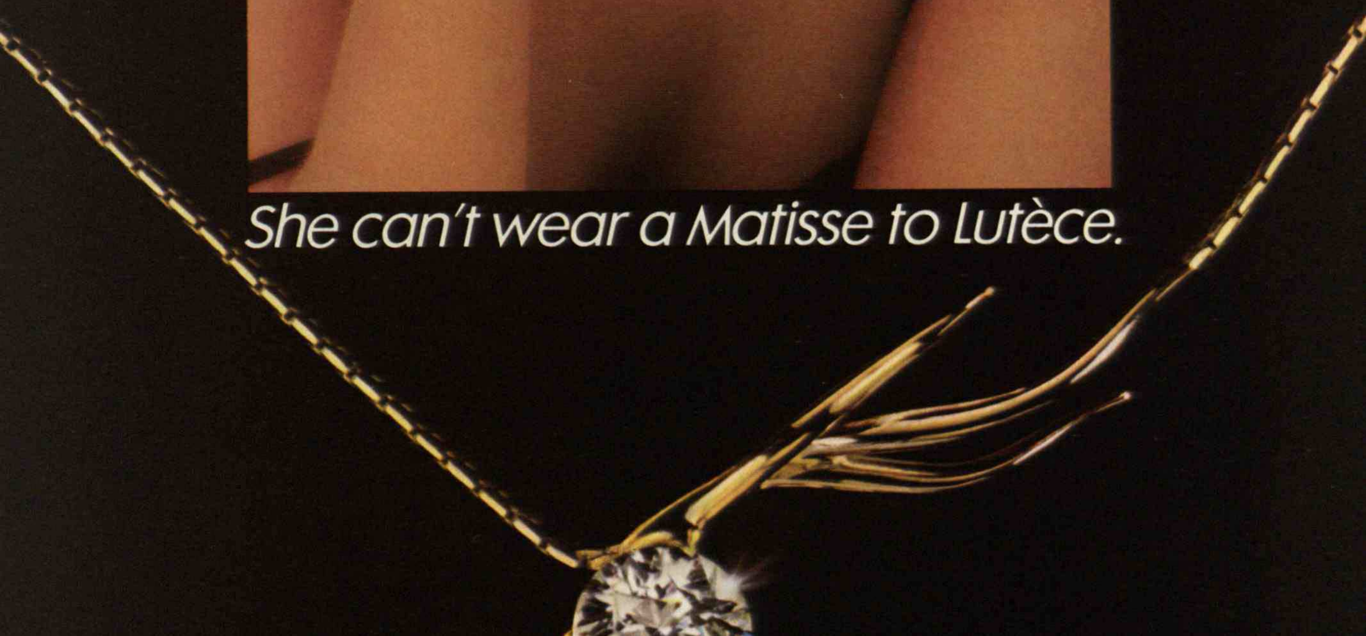
The Cargill researchers have also begun an unusual approach to wheat breeding. They are seeking out all the different varieties of wheat they can, crossing them randomly, and watching for interesting new genetic characteristics to emerge. In the past, wheat breeders would work with an established variety of wheat, introducing new characterstics one at a time through crossbreeding. "The idea was to work from strength, to build on what was already established," Cargill geneticist Bill Roberts explains. So this new approach—crossing almost everything with anything that can be found—has horrified the more conservative wheat breeders.

But the new approach has produced some interesting new combinations of characteristics. In the field behind the Cargill office, for example, researchers carefully recorded the characteristics in 430 new crosses planted in the fall of 1980. As expected, a few of these new types didn't survive the rigors of their first winter, while others were obviously too tall and spindly. However, a number of these "shotgun" crosses showed promise. A few were very vigorous, short in stature, produced many heads of wheat, and had relatively stiff stems that carried large heads.

So the possibilities are there; the work is underway. And it's from these, the new crosses and the old varieties, that the wheat of tomorrow will probably come. □

Robert Cooke is science editor of the Boston Globe.

She can't wear a Matisse to Lutèce.



Born out of fire and ice more than a hundred
million years ago. Every diamond is unique.
But a diamond this large is even more precious.
A gift so rare, it can never be measured.
Until you see the look in her eyes.

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A diamond is forever. De Beer

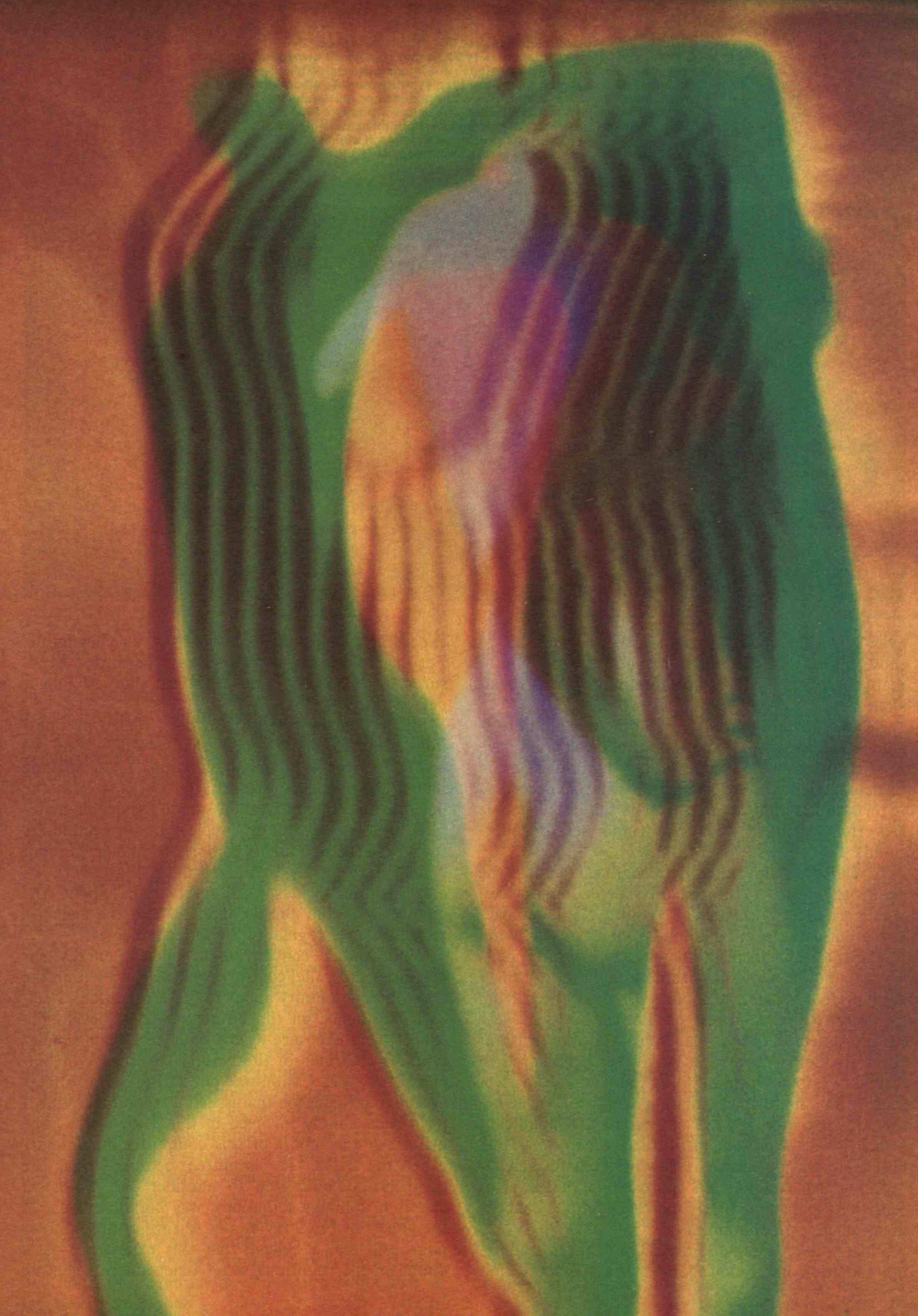
Cancer Risks from Ionizing Radiation

by Edward P. Radford, M.D.

IONIZING radiation and its effects on living organisms—especially through that most dreaded of all diseases, cancer—are not well understood. Though widely studied, the potential health risks from radiation exposure have been the subject of some of the most vehement and acrimonious confrontations of the past two decades.

There are several reasons for the disproportionate concern about ionizing radiation compared with other environmental hazards. First, the danger of a nuclear holocaust is now deeply embedded in our collective consciousness. The image of the mushroom clouds

Understanding of the effects of x-ray and gamma radiation has been hampered by the controversy surrounding their analysis and reporting.



The color illustrations for this article were made by Thomas K. Norton with a special color-synthesizing camera he developed. Originals, which can be two- or three-dimensional, are imaged through a black-and-white video system. Specific colors are then synthesized into electronically modified areas of the image. This camera does not reproduce full-color computer-graphic images; rather, the colors are created for the first time on the photographic film itself, in this case Polaroid type 559 ER. Mr. Norton is a research affiliate in arts and media technology at M.I.T.

over Hiroshima and Nagasaki, the devastation of those cities, and the long-term health problems of many survivors conjures up profound fear and revulsion.

Second, radiation in the environment is not detectable by our senses. Air and water pollution often have physical or chemical manifestations, but radiation can be detected only by special instruments and described in terms unfamiliar to the person on the street. People are often fearful of what they cannot see or understand.

A related but not generally recognized factor is the exquisite sensitivity of radiation detection devices, which are literally capable of counting single radioactive atoms. Radioactive fallout from a nuclear bomb test in the atmosphere can be quickly measured halfway around the world, for example, and the very small amounts of radioactive noble gases discharged from the Three Mile Island reactor after the accident were readily detected over Philadelphia and more distant cities. In both cases, radioactivity was measured in terms of atoms disintegrating per minute, representing an infinitesimal radiation exposure. Nevertheless, this radiation was feared by some as a significant health risk to present or future generations just because it was detectable. (New methods for analyzing chemical residues are approaching this level of sensitivity and are similarly increasing public concern about chemical pollutants.)

Finally, our understanding of the dangers of ionizing radiation has followed by many years the first exposures by users assured that risks were negligible. For example, early users of x-rays permitted exposures of themselves and their patients no longer deemed safe.

Public controversy has also been fueled by questions of nuclear energy policy that go well beyond the health hazards of ionizing radiation. These include international nuclear weapons policy as well as the possible diversion of weapons-grade fissionable materials by terrorist groups. Nuclear power epitomizes the new, large, and highly complex technologies about which many people have deep misgivings; there are corresponding widespread reservations about the credibility of the nuclear industry and the agencies responsible for regulating these technologies.

While public concern about nuclear energy has increased, a parallel controversy has grown within the scientific community about the interpretation of scientific evidence on the ultimate risk of developing cancer from exposure to low doses of ionizing radiation. As chairman of the National Academy of Sciences' Advisory Committee on the Biological Effects of Ionizing Radiation that issued its report last year, I have been closely involved in this controversy. The history of the report of this committee (commonly called the BEIR III committee, because it was the third NAS committee to consider the biological effects of ionizing radiation), was highly unusual in the annals of NAS reviews of scientific subjects (*see page 74*), and I believe that this experience casts doubt on the traditional ways independent scientific

appraisals of controversial technical issues are made available for public decision making.

Radiation and Cancer

To understand the elements of this controversy, some basic concepts about ionizing radiation, human cancer, and the evidence linking radiation to increasing risk of developing the disease must be understood. The radiation most commonly encountered by people is x-rays, mainly derived from the bombardment of a metal target by energetic electrons in a medical x-ray machine. Gamma radiation arising from nuclear disintegrations, such as that from radioactive elements used in the nuclear industry, is similar to x-rays. Both are energetic electromagnetic radiations that, because of their energy, are highly penetrating. Along their tracks through living tissues, these radiations occasionally strip electrons from the molecules of which body tissues are composed, producing sparsely distributed ionizations.

In technical terms, x-rays and gamma radiation that leave thin tracks of ionized particles in their wake are said to have low linear energy transfer (LET). In contrast, alpha particles (energetic helium nuclei) give up their energy quickly when penetrating human tissue to produce a densely ionized track; alpha radiation is thus high-LET radiation. Neutrons produce their effect through recoil mechanisms, primarily by imparting energy to hydrogen nuclei (protons) which, like alpha particles, are densely ionizing. In practice, this distinction between high-LET and low-LET radiation is not clear-cut; all radiation produces some recoil electrons in body tissues, resulting in some high-LET tracks even for x-rays and gamma radiation.

The biological effects of radiation are primarily due to the fact that the ion pairs that result from ionization, particularly in the water of body cells, yield highly reactive free radicals. These radicals can readily interact with molecules in the irradiated cells to break chemical bonds or produce other chemical changes. Because the nature and distribution of these highly reactive chemical products depends on the spatial distribution of the initial ionizations, the distinction between high-LET and low-LET radiation is important in determining the damage produced. And since most human-made sources produce chiefly low-LET radiation, determining the related risks—one assignment of the BEIR III committee—is crucial.

Studies of irradiated human populations suggest that ionizing radiation is an excellent initiator of human cancer through a mechanism involving the reaction of free radicals with cellular DNA. Indeed, radiation appears to be capable of producing cancer in nearly every tissue of the body.

We know that cancer develops in two or more stages, usually widely separated in time. The first stage—initiation—is now generally believed to involve transformation of the genetic code of one or more of the stem cells that act as the source of replenishment of all body cells. This transformation allows the descendant cells eventually to grow without normal restraints. Thus, the descendant cells become the seeds of a later cancer. The second stage of cancer development—promotion—involves an interference in the normal regulation of tissue growth. This second stage is still not well understood; it may involve more than one step and result from nonspecific processes, such as those related to aging, changes in immune mechanisms, chemical irritation of affected tissues, and infections—perhaps especially viral infections. The explanation for the very long latency period, during which the cells transformed by radiation evidently lie dormant, seems to be this: the probability of the promotional stage or stages occurring has to exceed a certain minimum if the growth restraints on the transformed cells are to be sufficiently relaxed for cancer to start.

The long time separation between the initiating event and the eventual development of cancer has great significance for our understanding of the causes of the disease. For if the risk of radiation-induced cancer remains increased for the rest of the life of exposed individuals, the true risk cannot fully be known until a population has been evaluated for essentially their entire life span following exposure. We have many more studies of the relation of human cancer risk to radiation exposure than for any other identified environmental carcinogens (with the possible exception of cigarettes). However, we still lack certain knowledge of the lifetime excess risk of cancer from radiation exposure because few of these studies have covered a sufficient time period. Thus, statements of cancer risk derived from present studies must be considered incomplete and may be underestimated.

A notable exception is radiation-induced leukemia. There is good evidence that the development of leukemia—cancer of the white blood cells—occurs after a latency period as short as two years following irradiation. It is also clear that most of the leukemia increase appears within 10 years of exposure and that

Research at Hiroshima and Nagasaki is an example of the best humanitarian impulse of scientific inquiry.

the increased risk becomes negligible after 25 or 30 years (when the radiation-induced cancers of other tissues may be reaching their full expression). Because of this marked difference, early research efforts centered on the relationship between leukemia and radiation exposure. But it is now evident that leukemia is atypical of radiation-induced cancers and is in fact a relatively minor consequence of radiation exposure.

Estimating the Risk of Radiation-Induced Cancer

The part of the BEIR III report dealing with cancer was the responsibility of the Subcommittee on Somatic Effects, of which I was chairman. (Somatic effects are those on body cells in general, as distinct from genetically transmitted effects on the critical cells of the gonads.) Because of the many uncertainties about the development of human cancer in relation to radiation exposure, there was agreement among members of the subcommittee that to quantitatively determine the cancer risk due to radiation exposure, we had to depend on epidemiological studies of cancer in exposed human populations. The specific goal would be to understand the relationship between the increase in cancer in the irradiated tissues and the radiation dose. With this understood, it should then be possible to predict the cancer risk for anyone exposed to radiation, such as the people near the radioactive gases released from the Three Mile Island reactor in March 1979.

Defining the cancer risk in such a situation requires taking into account not only the amount of radiation exposure but also factors such as dose rate (is a one-time radiation dose likely to produce more or less cancer than an equivalent dose spread out over time?), the quality of radiation (what are the relative effects of equal exposures to low-LET and high-LET radiation?), and especially the shape of the dose-response relationship over all doses (are high doses more or less likely to produce cancer than low doses when expressed per unit of dose?).

Most of the available data on radiation exposure have been derived from studies of people irradiated for medical purposes, with one notable exception: the follow-up study of the unfortunate people of Hiroshima and Nagasaki exposed to radiation from the atomic bombs dropped in 1945. An evaluation of the health status of a large number of survivors began soon after the bombing as a joint project of Japanese and American investigators. This evaluation has been pursued continuously since then, supported by both governments—a remarkable lifetime study that represents the best humanitarian impulse of scientific inquiry.

The Hiroshima and Nagasaki survivors constitute a large population, including both sexes and all ages, without any general preexisting medical condition that might otherwise affect their risk of subsequently developing cancer. The survivors were exposed to a wide range of doses of total-body radiation (depending on an individual's location at the instant of the bombings), and the dose in each case was thought to be known to within 30 percent accuracy. Moreover, data on the cause of death for those who died through 1974 was essentially complete.

There was also an important additional source of information about cancers in this population: tumor registries were established in the late 1950s to record every diagnosis of cancer in Hiroshima and Nagasaki from hospital records and other sources.

The Dose-Response Relationship

The first BEIR committee (BEIR I), which issued its report in 1972, adopted the so-called linear no-threshold dose-response curve as appropriate to describe the genetic and carcinogenic effects of radiation. That is, there was no "threshold" dose below which zero effect was assumed; any incremental increase in dose was considered to produce a proportionate increase in cancer risk, however small. This assumption of a linear no-threshold dose-response relationship for cancer induction caused some scientists to challenge the report's conclusions.

By the time the BEIR III committee convened, there was general agreement within the Somatic Effects Subcommittee that cancer risks due to radiation from natural causes on earth, however small, represented a minimum risk to which risks from human-caused radiation had to be added. The crucial question was whether the incremental risk of cancer was greater, less, or the same from a high dose as from a lower dose. Resolution of this question was especially important because, though many studies of radiation-induced human cancer involve relatively high doses, the BEIR III committee was convened to define the risk of the lower doses to which most people are likely to be exposed. Unfortunately, few studies of irradiated human populations offered dose-response data for a large-enough study population over a large-enough range of doses to permit empirical answers.

There was also general agreement within the Sub-

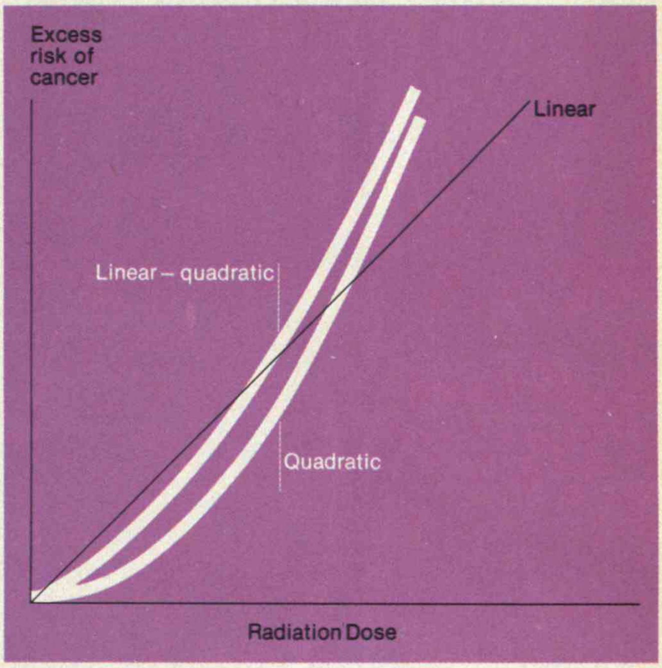
committee on Somatic Effects on the evidence that a given dose of high-LET radiation from alpha particles was more effective in causing cancer when given over a longer period of time than over a short period of time. For low-LET radiation, the evidence—largely from animal studies—was that the opposite was likely to be true. But in both cases the subcommittee felt from the human evidence that this effect of dose rate, given a fixed total dose, was of little significance.

For high-LET radiation, the evidence indicated that at low doses the dose-response relationship is linear—that is, the increase in cancer risk is proportionately related to the dose. There is no dose above zero for which the risk is zero; even the lowest exposure carries an element of risk.

However, members of the subcommittee disagreed on the appropriate form of the dose-response relationship specifically for low-LET radiation. The authors of the BEIR I report in 1972 had adopted the linear no-threshold relationship for all radiation, and members of the BEIR III subcommittee had agreed during the early stages that this approach would also be used to determine the cancer risks from low-LET radiation in the new report. Moreover, this was the dose-response model adopted by the Subcommittee on Genetic Effects of BEIR III.

The study populations in Hiroshima and Nagasaki were especially important for evaluating these questions because they were quite large and had been exposed to a wide range of doses. But there was a complication. According to a group at Oak Ridge that had studied this problem for many years, the ground-level exposure from the plutonium bomb exploded at Nagasaki was almost entirely due to gamma rays (low LET). But at Hiroshima, a substantial neutron (high-LET) component was thought to have been present in addition to gamma rays at ground level. Thus, the Hiroshima results were suspect for determining the shape of the dose-response relationship for low-LET radiation. No other human population had been exposed to whole-body doses of neutrons, and there was no empirical basis for separating the effects of the two kinds of radiation in Hiroshima unless the dose-response relationship for low-LET radiation could be defined independently. Obviously, the Nagasaki results offered this opportunity.

Because of the difference in topography of the two cities and the locations of the bomb detonations, the number of survivors exposed to radiation in Nagasaki was less than in Hiroshima, and therefore the statistical reliability of calculations of cancer risk at various



How do the risks of radiation-induced cancer relate to the total dose of ionizing radiation received by a human in his or her lifetime? The three relationships between the variables shown above figured in the controversies surrounding the 1980 report of the National Academy of Sciences on the effects of low-level radiation.

The linear relationship holds that there is no incremental exposure without risk and that the risk increases directly with the amount of exposure. The quadratic relationship holds that small amounts of radiation hold less proportional risk than larger ones. The linear-quadratic model, adopted in the academy's final report in 1980, represents a compromise: it shows essentially a linear relationship at low levels of dose, but at high levels of dose the risk increases disproportionately. The issue is significant for workplace radiation protection standards because the three different relationships show widely different cancer risks at low levels of dose.

dose levels among the Nagasaki survivors was not as high as in Hiroshima. When the fatal cancers were determined from death certificates for Nagasaki survivors up to 1974, the results for the different dose levels showed a very erratic dose-response relationship. A similar situation was found for the special case of leukemia induction in Nagasaki, but since only 22 leukemia deaths had then occurred among subjects with significant radiation exposure, a reliable dose-response relationship would not be expected. In contrast, the dose-response relationship for total fatal cancers among Hiroshima survivors was entirely consistent with the linear no-threshold relationship.
(Continued on page 76)

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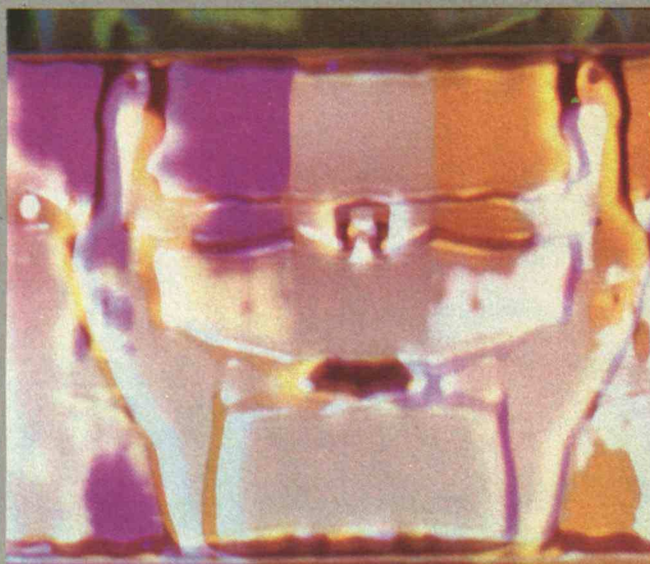
Scientific Controversy in the Public Domain

THE report of the National Academy of Sciences' (third) Advisory Committee on the Biological Effects of Ionizing Radiations (BEIR III) was intended to contribute significantly to the nation's policy on regulation of exposure to ionizing radiation. But its management and publication were so maladroit as to jeopardize this contribution.

The initial report of the BEIR III committee, approved by the review process of the National Academy of Sciences, was issued at a press conference on May 2, 1979, at which I presided as chairman of the committee and of its Subcommittee on Somatic Effects. Also present were two other members of the subcommittee, Harald H. Rossi and Edward Webster, who presented dissenting views on the conclusions dealing with risks of radiation-induced cancer.

Subsequent to that press conference, the then-president of the academy, Philip Handler, withdrew the report and appointed a special subcommittee, consisting of 7 of the 21 members of the full committee but specifically excluding Dr. Rossi and me, to prepare a new section dealing with cancer risks. No further meetings of the Subcommittee on Somatic Effects or the full BEIR III committee were ever held, but in July 1980 an "official" version of the BEIR III report was finally published, including dissenting statements by Dr. Rossi and myself, protesting (on either side of the issue) how the new section had been written.

How did this state of affairs come about among a group of reputable scientists with sufficient competence to have been selected for the BEIR III committee in the first place? And what does this unfortunate controversy mean for the status of the National Academy of Sciences as a source, through its review-committee system, of impartial reviews of scientific evidence bearing on public-policy issues—especially issues strongly polarized in the public domain?



Advocates as Regulators

To look at these problems we must review a little history. We are all aware that the U.S. technical community is now split into two opposing camps on nuclear energy, each of which is seeking to marshal scientific evidence to support its position—on one hand that nuclear energy is safe and presents less hazard to public health than other energy alternatives, on the other that radiation exposures are an inevitable result of nuclear technology and that risks from these exposures are unacceptable.

An important element in the controversy is the way nuclear energy was developed—initially by a handful of physicists and engineers in the Manhattan Project and later under the guidance of a scientific elite now institutionalized in such government-owned laboratories as Brookhaven, Argonne, and Los Alamos. These laboratories have not only developed nuclear-power technology; they have also conducted a great deal of the experimental work on the biological effects of ionizing radiation, much of it outstanding, on which many of the theoretical and experimental concepts on low-level radiation discussed in the accompanying article have been based. There have been some unusual aspects of this work:

☐ A large part of all U.S. research in this field was conducted in the national laboratories, with much less contribution by university investigators than in most other fields of biomedical research.

☐ These laboratories never developed expertise in human epidemiology or indeed public health in general, though their responsibilities impinge on both these fields.

☐ The laboratories were therefore not only almost single-handedly responsible for developing the technology; they also considered themselves uniquely qualified to estimate its possible harmful side-effects. Under these conditions, with their continuity dependent on the successful development of nuclear power, the laboratories had a vested interest in its acceptance.

The situation fostered a close-knit camaraderie among the laboratory scientists. They met frequently at national and international meetings that they were instrumental in organizing, and they were major contributors to the evaluation of radiation hazards conducted by groups such as the National Council on Radiological Protection and Measurements (NCRP) in the United States and the International Commission on Radiological Protection (ICRP). Indeed, the latter had such a limited budget that its membership was effectively limited to government employees whose expenses at frequent international meetings could be borne by their "sponsors."

Soon after World War II, the NCRP and the ICRP assumed responsibility for recommending exposure limits for radiation for both the general public and workers in the rapidly expanding nuclear industry. There was nothing unusual about semiprivate and self-perpetuating groups of scientists taking this responsibility; a similar group, the American Conference of Government Industrial Hygienists, had provided recommendations on occupational exposure limits to chemical hazards for many years. The unusual aspect was the regulators' commitment to the success of the technology whose hazards they were evaluating.

This informal arrangement with the NCRP ended in the U.S. around 1970 with passage of the National Environmental Policy Act, which established the Environmental Protection Agency (EPA), and the Occupational Safety and Health Act, which established the Occupational Safe-

ty and Health Administration (OSHA). These acts stipulated that the setting of standards was the responsibility of those answerable to political representatives. Because of the controversy over radioactive fallout from weapons testing, one of the first actions urged on the EPA was the support of an independent evaluation of the health risks from radiation. Thus was born the first National Academy of Sciences Committee on the Biological Effects of Ionizing Radiations (BEIR I).

Facts versus Votes

The BEIR I report (1972) was noteworthy for firmly adopting the linear no-threshold dose-response curve as appropriate for assessing the genetic and carcinogenic effects of radiation. It also contained an estimate of the consequences of a single radiation exposure, or one occurring at a steady rate every year, on cancer deaths in the United States. Because this population is so large, these anticipated excess cancer deaths, though a small percentage of the number of cancer deaths occurring each year in the U.S., turned out to be in the thousands—a figure that was inevitably taken out of context and seized upon by the antinuclear forces to give discomfort to the industry. Another consequence, not anticipated by the members of the BEIR I Committee (of which I was one), was that its methods of applying risk estimates were also used in other studies of human carcinogens identified by the mid-1970s.

This linear no-threshold approach simplified life for regulators because it meant that any increment of dose carried a proportional increment of risk. 'However, to the regulated it meant that any exposure, however small, carried some finite risk. Gone was the concept of a threshold or "safe" dose below which no health effect would occur. Moreover, setting nonzero standards for exposure limits implied that a level of risk could be devised that would be acceptable to those exposed. Both the regulators and the regulated were uncomfortable with this idea of reaching consensus by democratic procedures on an acceptable limit of risk, especially since the risks could be borne by people for whom the benefits of nuclear energy might not accrue. It is no wonder that many segments of the nuclear industry and the scientific community began a lively discussion of the BEIR I conclusion of a linear dose-response for low doses.

Despite these difficulties, the BEIR III Subcommittee on Somatic Effects resolved to use the linear no-threshold dose-response curve and to express risks as cancer incidence rather than mortality. But then came the decision by Philip Handler, president of the academy, to withdraw the first BEIR III draft report and convene a special committee to revise it before public release. The members of this special subcommittee, appointed by Dr. Handler in 1979, were persuaded by various lines of evidence to express risks only in terms of cancer deaths and to include the quadratic term in the dose-response curve.

The result was a reduction of about fivefold in the estimates of cancer risk. The disturbing aspect of this resolution is not the shape of the curve; it is the idea that scientific disagreements can be decided by vote. Because I could muster less than a majority of the subcommittee in my support, I must be wrong.

Several recent reports of academy committees have been characterized by similar disagreements, some even more vehemently contested than BEIR III. There are at least two reasons:

☐ The National Academy of Sciences has discouraged minority reports of its committees, urging that every effort be made to reach consensus. This inevitably fosters an "averaging" of different points of view that cloaks the essential elements of controversy.

☐ Especially for subjects that relate to controversial matters of public policy, the academy has sought representatives from the entire spectrum of opinion for its committees. This is a prescription for discord and—given the emphasis on consensus—ineffectiveness in the final report.

Scientists Before Their Peers

The BEIR III experience suggests that the select-committee approach to scientific evaluations in fields highly charged with economic and political implications is no longer tenable. The same is true of self-perpetuating standing committees such as the ICRP, which now clearly adopt the official positions of the governments for whom most of their members work without adequately considering the interests of those who are supposed to be protected.

The real tragedy of the BEIR III controversy is that the reputation of science and scientists has been tarnished. Extremists have been quick to seize the controversy to claim added credence for their opinions on the basis of the experts' lack of agreement. I had hoped that the BEIR III report could stand as a solid achievement and rebut claims by both sides; instead it was confusing and therefore gave ammunition to extremists. Moreover, the section on cancer risk quickly became obsolete (*see pages 77 to 78*).

If the National Academy of Sciences' review process no longer is adequate for impartial assessments of controversial scientific subjects, how then can such evaluations be reached from which to shape public policies? Congressional hearings simply involve presentations by individuals to legislators, staffs, and readers insufficiently knowledgeable to separate wheat from chaff. The scientific tradition for resolving differences—having researchers publish their evidence in refereed publications—is not only too slow but all too often leads merely to claims and counterclaims that emphasize only the evidence supporting a particular position. The traditional scientific literature will take years simply to resolve the complicated new data affecting our understanding of radiation-induced cancer.

A better approach might be to bring scientists together to explain and defend their positions before a panel of scientific peers sufficiently knowledgeable that omissions, errors, and misinterpretations can be made apparent. Such a confrontation should be open to the press and the public. An example was the public hearing on the role of mammography in the detection of breast cancer held by the National Cancer Institute in 1977.

Arthur R. Kantrowitz and others similarily propose to establish a "science court" where controversial subjects could be adjudicated. Such plans would represent a revolutionary change in the relationships between the usually quiet, arcane world of science and the cauldron of public debate. Though I am by no means certain that such proposals can be effectively implemented, this important issue must eventually be faced by the scientific community.—*E.P.R.* ☐

Radiation appears to be capable of producing cancer in nearly every tissue of the body.

But there were also results for cancer *incidence* (new cases, not necessarily fatal) from the tumor registries, including about the same number of cases from 1959 to 1970 as the cancer deaths from 1955 to 1974. When these data were used to determine the dose-response relationship, the results for both cities were similar and consistent with the linear no-threshold concept.

The Basis of the Disagreement

The reader is now in possession of all the scientific ingredients of the controversy among members of the BEIR III Subcomittee on Somatic Effects. To recapitulate briefly: The changes induced by radiation require many years or decades before becoming manifest as an increased cancer risk (leukemia is an exception), and thus very long follow-up is necessary to define lifetime risks. Studies of human populations exposed to radiation were the appropriate basis for defining cancer risk, and though numerous such studies were available, they generally offered far less than lifetime follow-up. The number of such investigations, from which the relationship between radiation dose and cancer response could be determined, was limited, the best being those of the A-bomb survivors in Nagasaki and Hiroshima. The Hiroshima findings could not be used to evaluate the effects of low-LET radiation because of exposure to neutrons in addition to gamma rays thought to have occurred in that city. The Nagasaki results, although related to low-LET gamma radiation exposure, were less reliable statistically because of the smaller population being studied. Cancer mortality determined from death certificates gave very equivocal dose-response relationships for low-LET radiation in Nagasaki, but the tumor-registry findings indicated that the dose-response relationship for both cities was similar and consistent with the linear no-threshold concept.

Based on these considerations, here is how the subcommittee dealt with the problem of the dose-response relationship for small doses of low-LET radiation. One subcommittee member, Harald H. Rossi of Columbia University, concluded that the appropriate relationship was *quadratic*—that is, the cancer risk from exposure to radiation was proportional to the square of the dose of low-LET radiation. He considered the total cancer and leukemia mortality data for Nagasaki, as well as some experimental results consistent with this idea. However, on the basis of the Nagasaki tumor-registry results, dose-response data from other human studies of thyroid cancer and cancer of the female breast in irradiated populations, and new results from studies of cell transformation by x-radiation, I felt strongly that the *linear* no-threshold relationship was appropriate.

Dr. Rossi and I agreed that the dose-response relationship for each kind of cancer need not be the same. For example, there is evidence that induction of skin cancer by radiation shows a markedly curvilinear dose-response relationship (low doses produce little effect and high doses produce a disproportionately higher effect). For this reason, the subcommittee agreed to omit skin cancer from consideration of the total cancer risk.

Another important conclusion was that all the studies of cancer in populations exposed to low-LET radiation other than the Japanese gave a total cancer risk based on the linear hypothesis remarkably consistent with the Nagasaki tumor-registry results. In short, the total risk of cancer incidence per unit of dose in groups given partial-body irradiation in many Western countries was similar to that found for the Japanese, despite differences in the usual cancer rates for these countries. This concordance of many results seemed to me strong support for the risk estimates derived from them.

I also considered reliance on cancer mortality data, when incidence data were available, contrary to established epidemiological principles. Death certificates are known to be poor indicators of the extent of many diseases, and cancers can be significantly underreported through diagnostic errors or if particular cancers are frequently cured or arrested.

In the first draft of its report, the Subcommittee on Somatic Effects had agreed to accept the linear dose-response relationship for the risk of cancer from low-LET radiation. But there were dissenters, and—in a move essentially without precedent (*see the accompanying essay on page 74*)—the academy withdrew this first draft and returned it for revision to a special subcommittee, of which neither Dr. Rossi nor I were members.

Lower Risk with a Linear-Quadratic Model

For the final version of the section on cancer risk of BEIR III, this special group opted for a compromise between my view and that of Dr. Rossi by using the so-called *linear-quadratic* model as the basis for determining risks for low-LET radiation at low doses. That is, they proposed a no-threshold relationship but

Air and water pollution
often have physical or chemical manifestations,
but radiation can be detected only by
special instruments.

with both linear and quadratic elements. A strong factor in this decision was the erratic dose-response data for cancer mortality in Nagasaki. The special group pointed out that statistical fitting of the linear-quadratic model to the results from the tumor registries in both cities showed that the quadratic component was negligible, but otherwise they largely ignored cancer incidence data and presented the final estimates of risk in terms of cancer deaths only.

The result of these changes in the report was that the cancer risk at lower doses of low-LET radiation was somewhat less per unit of dose than estimates recalculated from the first BEIR report in 1972, which presented a linear model. However, the new BEIR III estimates were somewhat larger than the values actually given in BEIR I, because in that report the excess risks for radiation-induced cancers were given only for the period over which observations had been carried out, in contrast to the recalculations presented in BEIR III, in which lifetime risks were projected.

In practical terms, what difference did these approaches make? The official BEIR III estimates of fatal cancer yield a 0.5 to 1.4 percent increase in cancer deaths in 1 million persons exposed once to 10 rads of low-level radiation. Based on the normally expected rate of about 165,000 cancer deaths from all causes in 1 million persons, this would be approximately 750 to 2,300 excess deaths. (The official report failed to emphasize that the cancer risk for women was about twice as high as that for men.)

The academy's press release summarizing the BEIR III findings pointed out that 10 rads is "far greater than radiation exposures encountered in daily life. The national average is approximately one-fifth of a rad per year, almost all of which comes from natural sources (about one-tenth rad) and medical and dental x-rays." It is much greater than the highest dose (one-tenth rad) received by people around Three Mile Island.

A Fivefold Difference in Risk

How do the other two methods of extrapolation compare with this result? For this answer I have averaged risks for each sex and the effect of different lifetime projection models. Dr. Rossi's dose-squared approach led to a lifetime risk of death per rad about one-eighth of the BEIR III value, while the linear model I advocated gave about 2.3 times the BEIR III risk of death, and the risk of cancer incidence almost 5 times. Thus, the range of risk estimates was almost fortyfold. The official version of BEIR III made much of this wide range, implying that the risks of low-LET radiation were still not well known quantitatively. But it is important to note that if Dr. Rossi's model is eliminated, the range of risk estimates is only fivefold.

If this analysis seems to give Dr. Rossi's position short shrift, it is because I have found virtually no one versed in this field who supports it. It runs contrary to most of the theoretical work on radiation effects on cellular DNA, and new evidence from Hiroshima and Nagasaki clearly invalidates the basis for Dr. Rossi's position.

In fairness to the group that adopted the linear-quadratic model, I should note that there is substantial theoretical and experimental evidence supporting it. But this model fails to account for the observation that at high dose rates the cancer effect of high doses of radiation may be *reduced* below that observed at lower doses. This is presumably because high doses kill essentially all the irradiated cells, leaving few or no cells in which the transformation to cancer can occur. Evidence has been obtained in women given high doses and dose rates of x-rays to the pelvic region in the treatment of uterine cancer: although the pelvic bone marrow is heavily exposed, no excess leukemia has been observed in these women, whereas when bone marrow is irradiated at lower doses for other reasons, excess leukemia has consistently been found.

This "cell-killing" effect can be represented by multiplying the linear-quadratic expression by a negative exponential term. When this is done, the experimental term very nearly offsets the dose-squared term in the low-dose range, resulting in a nearly straight-line dose-response relationship. Thus, the linear no-threshold dose-response curve can be considered an approximation of this more complex dose-response curve.

In view of the uncertainties in the whole process of determining cancer risk in human groups from incomplete studies, is a fivefold difference in perceived cancer risk important? It is, indeed: a fivefold greater risk could considerably affect the exposure limits set for workers in nuclear facilities or in industry in general, for example. The whole-body exposure limit for workers of five rads per year could lead, after 30 or more years of working life, to a cancer risk that I believe is unacceptable, especially for women.

In view of the fact that this fivefold uncertainty stems in part from the incompleteness of lifetime studies, it is important to maintain a regular review of new data.

I believe that if exposure can be kept well below doses from background radiation, the cancer risk will be small enough to be acceptable to society.

Indeed, even while the BEIR III committee was meeting in 1977 and 1978, a dramatic modification of the data on the radiation received by the Japanese survivors was underway.

New Evidence and New Conclusions

In 1976 a Los Alamos group studying the output from the two atomic bombs used in Japan concluded that the energy spectrum of the neutrons escaping from the bombs was different from that previously thought to be present, especially in Hiroshima. These results stimulated several new studies of ground-level neutron doses in both cities, and two investigators at the Lawrence-Livermore Laboratory, William Loewe and Edgar Mendelsohn, reported in 1980 that the previous (1965) neutron and gamma-ray dose estimates were in error. This was partly because the moisture content of the air in the Japanese cities had been seriously underestimated and partly because of the new data from Los Alamos.

The new conclusion from the Lawrence-Livermore study was that the neutron radiation had been overstated in Hiroshima by a factor of 5 to 10, depending on the distance from the bomb. For Nagasaki, the new appraisal reduced the earlier estimates of neutron dose at ground level, which had been small anyway, by a factor of 2 to 3. It now appears that, with the exception of the most highly exposed groups in Hiroshima (those closest to the detonation), there was no neutron exposure of any significance in either city—a striking change. There are also new assessments of the gamma-ray doses: doses at Nagasaki are now believed to have been at least 30 percent lower than previously thought and those at Hiroshima somewhat higher.

These changes have two significant implications for the BEIR III results. All the interminable arguments of the Subcommittee on Somatic Effects about assigning the difference in cancer mortality in the two cities to neutron irradiation are no longer relevant. In fact, there now appears to be no reason why the results for the two cities should not be combined, thereby strengthening the ultimate reliability of the dose-response interpretation. Second, the new gamma-ray dosimetry modifications mean that the tumor-registry dose-response relationship for cancer incidence is very close for the two cities, and both appear to fit the linear hypothesis well. (A final interpretation of these data will have to await a redetermination of the individual dose calculations for the 80,000 people in the study population.)

New information has also recently become available from further follow-up cancer studies in the two cities through 1978. The Nagasaki tumor registry has been updated to include all cases from 1959 to 1978—a total of over 1,400 cases, twice as many as were observed up to 1970, the follow-up time available to the BEIR III Somatic Effects Subcommittee. These data show that new cases are appearing in large numbers as new age groups reach the "cancer age," and the cancer risk per unit of dose actually observed in Nagasaki is now much higher than the 1970 follow-up indicated, especially if the new values for gamma-ray doses are applied. Moreover, we can now understand why the cancer mortality data, especially for Nagaski, will always be less reliable than the tumor-registry results in defining cancer risk. This is because the diagnosis of many types of cancer, especially in the younger segment of the study population (proportionally larger in Nagasaki than in Hiroshima), precedes death by many years. Many death certificates of cancer victims make no reference to the disease if the cancer is arrested or some other fatal event intervenes. Especially at this stage, with the cancer rate in the Nagasaki study population rising, tumor-registry results are thus much more indicative than death records of the cancer toll.

I am convinced that much of the technical information on which the final BEIR III estimates of cancer risk depended is obsolete and that new estimates of the dangers of ionizing radiation are needed. The new evidence indicates that the cancer risks are substantially higher than the BEIR III report concluded.

Nevertheless, the health risks from exposure to ionizing radiation have been exaggerated in the minds of the public. I believe that if exposure can be kept well below doses from background radiation, the cancer risk will be small enough to be acceptable to society. The problem of risks of cancer to workers in the industry must still be resolved.

Edward P. Radford is professor of epidemiology at the Graduate School of Public Health of the University of Pittsburgh, where he is director of the Center for Environmental Epidemiology. He prepared for Harvard Medical School (M.D. 1946) at M.I.T. (S.B. 1944).

TRENDS

Transportation

Technology for the ATC Muddle

When members of the Professional Air-Traffic Controllers Organization walked away from their radars and radios late last summer, they abandoned a complex, obsolescent computer system based on a philosophy of air traffic control that may also be obsolete.

Today's National Airspace System (NAS) was designed in the 1960s to do what no computer system had ever done before: integrate data from as many as 20 computer sites, gather inputs from 100 long-range radar systems and several thousand other data sources, and contain redundancies to assure that the failure of any element would not bring the whole system to a crashing standstill. Its success was a major milestone in the field of information management, giving air-traffic controllers the basis for absolute and dependable control over U.S. air traffic.

But in the decade since NAS became operational, air traffic has increased so much that the system has been pushed to its limits and its monolithic control philosophy called into question; the technology of information handling has also advanced. Before the Federal Aviation Administration (FAA) reduced airline schedules in the wake of the PATCO job action, says Professor Hoo-Min D. Toong of M.I.T.'s Center for Information Systems Research, loads were so great during peak periods that NAS computers sometimes took as long as seven seconds (compared with the two seconds prescribed in the specifications) to present new data. And redundancies that were built into the system in the 1960s, innovative for that time, "are simply not sufficient to prevent random and unpredictable interruptions of service." Professor Toong reports that many critics characterize the NAS as a "complex, inefficient, and unwieldy system" by today's standards.

Correcting the problem will not be easy. Even if design work started today, the major new system needed for U.S. air-traffic management could not be ready until the 1990s, when today's NAS would be hopelessly inadequate unless traffic restrictions such as those now in place were continued.

One alternative, which no one seems to like, is to add auxiliary processors to the present NAS to augment its computing

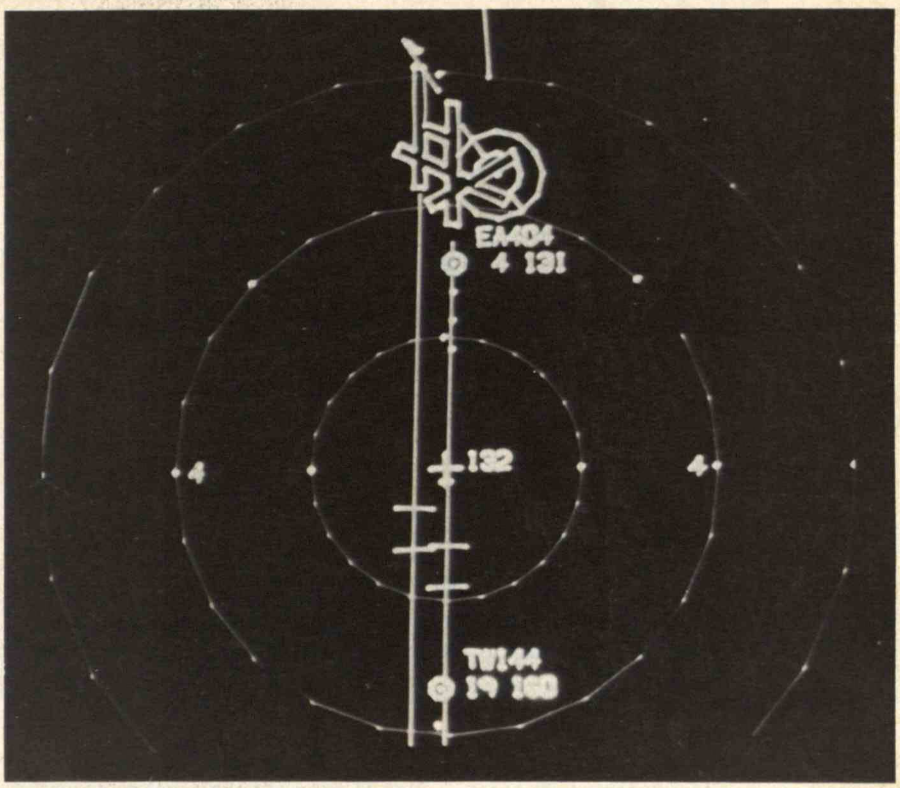
power while a new system is designed and built; this, says Professor Toong, a consultant to the FAA, would make necessary "excessive communication" between the present system and its new auxiliaries. A better idea, says Professor Toong, is to replace selected obsolete NAS hardware with modern equivalents that are faster at computation and can store more information. If this new hardware is compatible with the 1990 NAS replacement system, then this interim measure becomes a way to transform today's NAS into its successor on a "gradual, modular basis."

A third approach, advocated by Mark E. Connelly of M.I.T.'s Laboratory for Information and Decision Systems, is to make a fundamental change in air-traffic control strategy: move to a decentralized system in which pilots become participants with controllers in the process of staying on course and avoiding collisions.

For nearly a decade Mr. Connelly and his associates have been developing and testing an airborne traffic situation display (ATSD) that would put in front of every pilot a comprehensive, computer-generated map with the pilot's aircraft fixed in the center of the display. Also indicated would be major landmarks and routes, weather features such as fronts and thunderstorms, airport runways and holding patterns, ground-based obstacles such as high towers and hills, and the identity, altitude, speed, and direction of all other aircraft in radar range—typically from a distance of from 3 to 30 nautical miles. By showing airport runways, ATSD would help pilots space themselves so precisely in their landing approaches that the minimum spacing between aircraft could be reduced. Indeed, says Mr. Connelly, simulator tests by commercial pilots suggest that ATSD is "essential to get pilots to accept interleaved landings and takeoffs at high throughput rates on a single runway."

With an ATSD display in the cockpit, every pilot would have enough information to understand controllers' directions—and even to make many of them unnecessary. It would enable pilots "to detect and resolve most abnormal situations extemporaneously in the air, thus relieving the automated, ground-based system of this difficult and costly responsibility." The point is, Mr. Connelly says, that "automation works best when applied to fixed, well-defined tasks"; ATSD could relieve the NAS system of the need to respond to the full spectrum of normal and abnormal events that characterizes today's air-traffic control.—*J.M* □

You are the pilot on your final approach to the airport at the top of this picture, and this airborne traffic situation display (ATSD) is the central feature of your cockpit. It shows that your own aircraft, at the center of the display, is precisely on the proper course proceeding at 132 knots. One and one-half miles ahead of you is Eastern flight 404, altitude 400 feet flying at 131 knots. Behind you, one and one-half miles away, is TWA flight 144, at 1,900 feet, flying at 160 knots, on a correct approach to the same runway. There are no other aircraft within six miles to the side or ahead of you. Such ATSDs, which could decentralize air-traffic control responsibilities, are well within the state of the art and could be a major component of the next U.S. National Airspace System.



A Risky Move Against PATCO

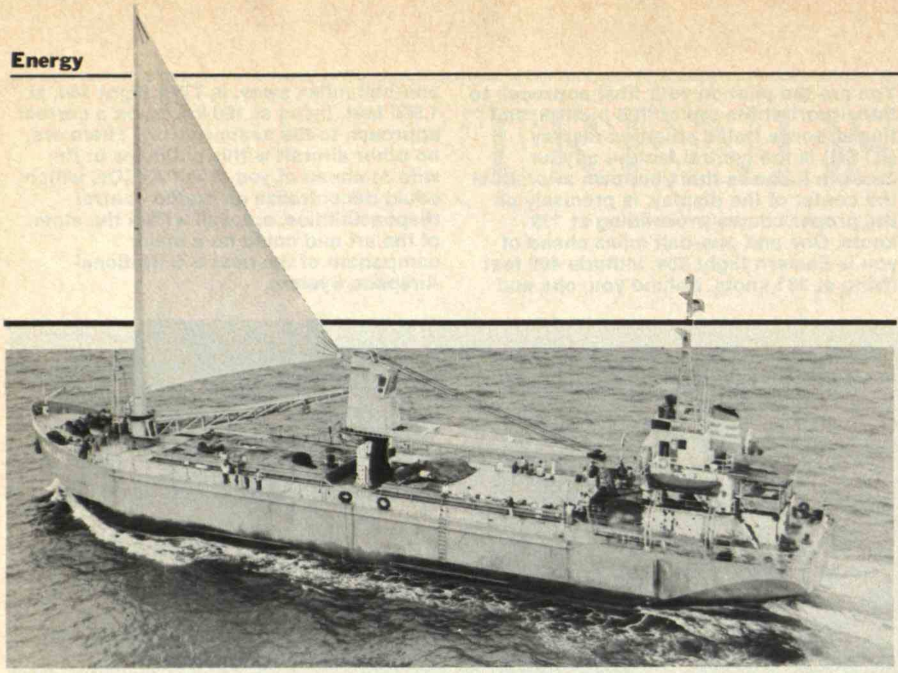
Despite his public approval, President Ronald Reagan's power play against the members of the Professional Air-Traffic Controllers Organization (PATCO) may backfire. The president is likely to have to "save face," and meanwhile the gulf has been widened between labor and management in the public sector, says Robert B. McKersie, professor of industrial relations in M.I.T.'s Sloan School of Management.

"As time passes," predicts Professor McKersie, "the air controllers may be seen more and more as victims, if not martyrs, in a major showdown between the union movement and the administration." And because the controllers will in fact be hard to replace, some face saving is likely to be necessary: "Somewhere along the line," says Professor McKersie, "someone sitting in authority will be impressed by the argument that the punishment exceeds the crime."

Two steps would help the government "regain control," he says:

□ Restructure the institutions responsible for the problem. If the fact that the Federal Aviation Administration (FAA) failed to come to grips with "a severe quality-of-work problem" exemplifies President Reagan's contention that "government does not know how to run programs effectively," then the FAA's functions should be turned over to a regulated utility so that incentives of the private sector come to bear.

□ Obtain a "third-party" presence to resolve the problem. "To ask the agency and the higher levels of government that have been unable to cope with this situation in the past to be the sole architects of reform is not wise," says Professor McKersie. □



The look of the future in cargo ships. In "The New Age of Sail Has Diesel Aboard" (August/September 1981), the next step in the development of large motor-sailing cargo ships was to be the construction and testing of a 2,000-ton prototype.

The successful completion of sea trials by just such a prototype was announced late last fall by Lloyd Bergeson, president of Wind Ship Development Corp., the designers of the system. It is the *Mini-Lace* (above), a 3,000-deadweight-ton vessel owned and operated by Ceres Hellenic Shipping Enterprises, Ltd. of Piraeus, Greece.

The *Mini-Lace* carries an unstayed mast that is rotated for furling, unfurling, and trimming the triangular, 3,000-square-foot Dacron sail by means of hydraulically powered winches and related gear controlled from the bridge. According to Mr. Bergeson, it's the "first substantial, modern auxiliary sailing rig in the world to be put on a commercial vessel for regular service."—*L.A.P.* □

Energy

Cooling Power with Less Water

Most electric plants in the United States have traditionally been cooled with water drawn from nearby lakes, rivers, and oceans, the water being returned to its natural source bearing the plant's surplus—rejected—heat. But with environmental concern over thermal pollution and the effects of aquatic organisms that are drawn through the plant's condenser systems, such "once-through" cooling is in disfavor. Most power plants now planned for construction include "wet" cooling towers, where cooling water is sprayed through a draft of air and then collected for reuse.

The heat is thus rejected into the atmosphere instead of the water body. But water lost to evaporation—of the order of 15 million gallons per day for a 1,000-megawatt plant—must be replaced, and water supply problems promise to be an important constraint. Indeed, the U.S. Water Resources Council estimates that under present design plans, power-plant cooling will account for about 40 percent of the growth in nonagricultural water consumption between now and the year 2000.

Additional drawbacks include the large capital costs of wet cooling—now estimated to be in the range of $100 million for a 1000-megawatt unit—and higher operational costs (and thus increased fuel consumption) owing to decreased efficiency of power generation.

Is the wholesale adoption of wet cooling towers necessary? With modest relaxation of thermal pollution guidelines, conventional once-through cooling systems might be possible in at least half of the plants now planned for construction before 2000, according to an analysis by E. Eric Adams and John J. Shaw of the M.I.T. Energy Laboratory and Professor Donald R.F. Harleman, director of M.I.T.'s Parsons Laboratory for Water Resources and Hydrodynamics. Other ways to obtain the benefits of once-through cooling include the use of "heat sinks" such as large reservoirs and inland waterways—the California Aquaduct, for example.

In locations where once-through cooling is not feasible, other forms of closed-cycle cooling may be practical:

□ "Dry/wet" cooling towers involving either separate dry and wet modules or hybrid towers. In such systems most cooling is accomplished by air forced over finned tubes containing the water to be cooled. However, equipment is also included for more efficient evaporative cooling in hot weather (when dry cooling is least efficient) or in periods of peak power demand when cooling performance is most critical.

□ Cooling ponds in which heated water is recirculated, gradually dissipating heat to the atmosphere. Ponds require large areas—on the order of 1,000 acres for a 1000-megawatt plant, but they offer a number of advantages over other closed-cycle cooling systems. These include lower operating and maintenance costs, more consistent thermal performance, and the ability to store water during periods of low flow or exceptional demand for water for other uses, such as agricultural irrigation.

□ Use of lower-quality water, including agricultural wastewater or brackish surface or groundwater. Although there may be environmental and engineering problems with such sources, their use reduces the competition for freshwater.

The growing demand for limited water supplies and accelerated development of Western energy resources highlights the problem of efficient water use. But the real issue, say the M.I.T. engineers, is the lack of "a common framework for optimal design, performance prediction, and cost evaluation for the entire spectrum of cooling-system alternatives."—*J.M.* □

Coal: Balancing Payments by 1990

The United States has the lion's share of world coal. But this vast energy resource has not yet proved to be a lever for offsetting the effects of heavy purchases from OPEC on our chronically unfavorable balance of trade.

The reason is simple, says D. Alec Sargent in an analysis prepared for the M.I.T. Energy Laboratory. Ninety percent of South African coal miners are black, and their average earnings are $1,490 a year (the 10 percent of South African coal miners who are white earn an annual average of $12,305). As a result, South African coal was sold in Rotterdam in 1979 at an average price of $1.38 per million Btu's, compared with U.S. coal exported through Mobile, Ala., at $1.70. In 1979 some 22 million tons of South African "thermal" coal (coal best used to produce heat, in contrast to the metallurgical coal required for coke for steelmaking) was burned in Western Europe and only 3 million tons of U.S. coal. Australian was the lowest-priced "thermal" coal in Yokohama in 1979 at

$1.19 per million Btu's, compared with South African coal at $1.40 and U.S. coal exported through Los Angeles at $1.71.

But by 1990 the tables may turn—at least as far as Europe is concerned. By then, Dr. Sargent forecasts, rapidly rising labor costs in South Africa—the result of blacks gaining long-denied civil rights—will have brought the price of coal on the pier at Richards Bay, South Africa, to $2.50 per million Btu's, up sharply from today's 90 cents. If U.S. "thermal" coal prices rise an average of 5 percent a year from now to 1990, the price at Mobile will then be $2.86, and when delivery costs are added U.S. coal will be a better buy than South African in Europe.

Two other factors will also make U.S. coal more attractive by then, says Dr. Sargent: South African export restrictions, designed to conserve resources and avoid industrial turmoil, and Europe's bias against apartheid. If demand grows as Dr. Sargent expects, the United States might find a market for as much as 100 million tons of coal a year in Western Europe by 1990, a startling increase from today's 3 million tons.

The Japanese coal market, which will grow even more dramatically, will probably belong to Australia and Canada, says Dr. Sargent. Indeed, the major uncertainty in his forecast involves these two coal producers: can they beat out the United States for the European market by posting cost increases of less than 5 percent a year between now and 1990?—*J.M.* □

JIM CHIROS

Business

How to Metricate (and Stay Out of Court)

Converting the products of U.S. technology from English to metric measure involves standardization and perhaps industrywide collaboration, in addition to the obvious matter of switching gages, scales, and tables. Components, after all, must fit together. Such forums among competing groups of manufacturers, suppliers, and others arguably could breach the nation's antitrust laws, which prohibit contracts, combinations, and conspiracies that could restrain trade.

But Daniel Payser, general counsel for the U.S. Metric Board, the federal agency created by the Metric Conversion Act of 1975 to oversee the nation's changeover to the metric system, says the issue of antitrust violation may be overemphasized by some corporations as an artifice to stall the metrication process. Overly cautious approaches to metrication—as well as time-consuming antitrust litigation—could serve the interests of companies that want to extend the lives of existing capital plant and inventories.

Such delays would add to the frustrations of many businesses that view metrication as a major cost-cutting opportunity to standardize products and minimize inventories. Mr. Payser observes that conversion to the metric system is not mandated by law, but only "countenanced and expected," and progress therefore depends on the private sector. For engineers and managers who want to forestall unnecessary delays—as well as the risk of antitrust action—here are six suggestions from the U.S. Metric Board:

□ Publicize all meetings—even small, in-house staff meetings—at which metrication is discussed. Both agendas and minutes should be open to all.

□ Distribute throughout the industry—and to the general public—notice of target dates for conversion, and provide a method and adequate time for hearing comments and complaints.

□ Avoid discussing the prices of proposed metric products, whether the news is bad or good. ("However desirable agreements *not* to raise prices might be from a public-relations standpoint," says the board, "the antitrust laws simply do not permit such agreements.")

□ Avoid discussing specific costs of conversion and how they may be defrayed. An example of possible mischief: if one company says it will pass on conversion costs to customers, the incentive for others within the industry to "internalize" these costs may be nullified and price competition inhibited.

□ Don't discuss the size of inventories. The board singled out this topic as particularly risky, and notes that such discussions "are viewed with deep suspicion by government antitrust enforcement agencies."

□ Don't divulge specific production or marketing plans.

However, the threat of antitrust litigation, should these guidelines not be followed, is minimal. The courts have in general enforced the antitrust provisions of the Sherman Act and the Federal Trade Commission Act with a "rule of reason." They have come down hard only on actions that "unduly" restrain trade, such as price fixing and group boycotts, that are patently inconsistent with free competition. Such *per se* offenses are considered unlawful despite any attempted justification and have led to the only antitrust findings to date.—*L.A.P.* □

Last Line

Computers: The Human Problem

The very excellence with which some computers do their jobs is creating problems for the humans they were supposed to assist.

The problem doesn't lie with computers that merely juggle data at lightning speed for their users to consider in making decisions. Things become thorny when machines can *act* on their findings, in effect dispossessing humans of portions of their responsibility and relegating them to the status of simple-minded button-pusher; or when computers stand as agents of constant surveillance of worker performance; or, perhaps most threatening, when they perform jobs once handled by humans.

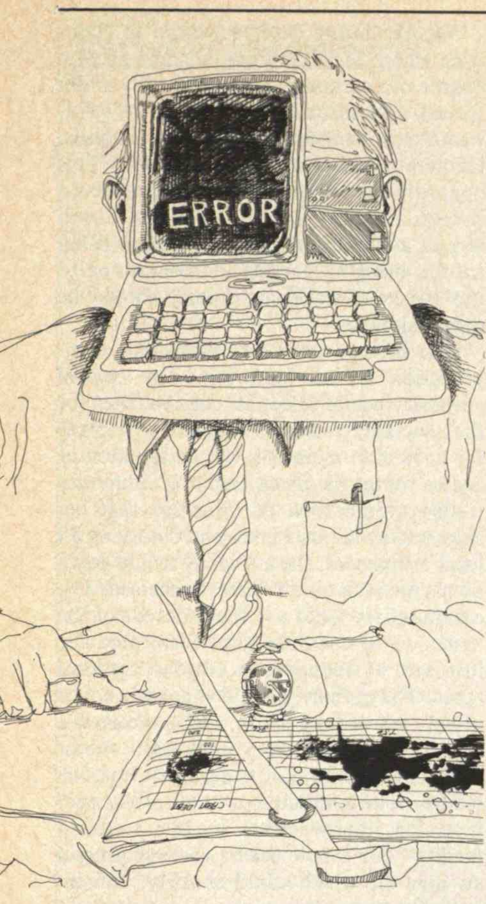
Conventional wisdom in management theory holds that "the less dependence upon human intervention, the better the work will be executed," notes Shoshanah Zuboff in a report prepared at the Center for Information Systems Research at M.I.T. (she is now an assistant professor at the Harvard Business School). But that approach fails to address the effect of computerization on the perceptions of affected personnel. Professionals reduced to "fail-safe systems" begin to feel "insignificant and overwhelmed," she says, and morale and motivation are likely to plummet.

The resulting fear of powerlessness and a concomitant loss of status can cause workers to be less efficient and even to perform "retaliatory" acts, reports Professor Zuboff. These results can be unexpected—and potentially costly, as in these cases:

☐ Employees in a highly computerized newspaper printing plant take "gleeful pride in systems breakdowns." Outsmarting the system becomes the most challenging aspect of their jobs.

☐ An accountant who seeks to retain "some sense of control" over her job recalculates results already performed by a new computer, reasoning, "I don't feel that I really know the data unless I can get my hands on it, so I have to rework it manually."

☐ An experienced bill collector, frustrated by having his work load dictated by a computer, perceives that he can regain "some sense of mastery by keying fictitious data into the system of account files" (managers were puzzled by the occasional mismatch of high productivity figures and low monthly revenues.) He told Professor Zuboff that the computer makes work



PAUL FISCH

"more intense," although he can actually do some jobs faster without it.

□ A regional auditor for a bank now receives financial information from terminals in branch offices and subsequently no longer travels to these offices, interacts with their personnel, or examines books. "The job has become very abstract," he reported. "I may be auditing, but I don't *feel* like I'm auditing."

The obvious conclusion, says Professor Zuboff: "If employees depend upon the computer system to accomplish their work, but the system is experienced as an enemy, then the quality of work must suffer."

The solution: make friend out of *perceived* foe.

To achieve this conversion, she recommends that managers contemplating computerization could ease stress, for example, by developing compensatory training opportunities, reward systems, and educational programs, more explicit and accessible chances for career advancement, and the opportunity to participate in the design and implementation of the new system.

Following just such an approach, managers in a unionized Volvo plant in Kalmar, Sweden, are rethinking the use of a computer-activated flashing red warning light that signals "quality-control problems" on an assembly line. Workers insisted that a foreman be reassigned that supervisory function, complaining that the computer's means of communication was "unilateral" and that it could not give them an explanation of the problem.

The Communications Workers of America, in recent contract talks with the American Telephone & Telegraph Co., urged the formation of committees of workers and managers to discuss the "implications of technological change." CWA members had reacted strongly against being monitored by computers. In a profound summary statement they noted that the resulting stress represents a "qualitatively new kind of workplace problem."—*L.A.P.* □

Wilson/Continued from page 11

volume of each could be recorded, and a formula devised that reflects the relative costs of litter cleanup. A tax could then be levied on each commercial category to pay for litter cleanup nationwide. The tax should be displayed on each product, so that purchasers realize proper disposal of the discards would reduce the tax allotted and cut the price of the product.

Promotion of Local Recycling. A principal benefit of local recycling of paper, rags, and bottles is that the materials are removed from the waste stream, reducing the costs of pickup and disposal of the remaining solid wastes. In my community of Cambridge, Mass., we recently passed an ordinance changing the status of firms known, disparagingly, as "scavengers." They would pick up newspapers from trash containers (many people from long—and good—habits still bundle their newspapers). Previously, removing materials from trash containers was outlawed. Now the city council recognizes that scavengers (now called recyclers) reduce the costs of trash pickup and disposal, and seeks not only to license them to pick up newspapers in certain areas of the city each week, but has offered to pay the difference whenever the local purchase price drops below $15 per ton. If successful—the concept has been adopted by the industry-sponsored Corporation for a Cleaner Commonwealth—this might be extended to bottles and cans.

Promotion of National Recycling. On the national level, recycling is desirable when scarce resources must be conserved. To some extent, the amount of recycling is a function of relative wealth—the poorer the society, the more recycling occurs. But recycling is also greatly affected by national policy. In the United States, there is relatively little recycling of wastes even for energy, despite the energy shortage, because national policy has kept energy prices low. Energy is consequently wasted on an enormous scale. The imposition of a tax on all energy from scarce resources, such as petroleum and natural gas, would have very desirable consequences in stimulating both conservation and recycling. (The energy obtained from waste would, of course, be tax exempt).

Other scarce resources—chromium, tin, lead, zinc, and so forth—should also be taxed when first imported or mined. There would be no tax on these substances when they are recycled, thus providing an incentive for recycling. Water should likewise be taxed in dry areas if the existing price is low enough to encourage waste. All taxes from scarce resources should immediately be recycled as reductions in income taxes, or negative income taxes, in equal increments to all adult residents.

Facility-Siting Compensation. In countries where local communities are given a degree of autonomy, there is usually widespread opposition to the siting of solid-waste-treatment facilities such as landfills, incinerators, and recycling centers. This opposition is understandable because even if such a facility is neat and quiet, it will attract a stream of noisy and refuse-laden trucks, bringing danger and congestion to the streets. So the community should be compensated.

One method for determining fair compensation is the following: The central authority would select all possible sites for the new facility and draw up tentative plans for each site, including the designation of access routes for truck traffic. Community leaders would then be informed that besides paying all local taxes and observing all local ordinances, the authority would pay a bonus for each ton of wastes processed. The communities could use the proceeds of the bonus to compensate local residents—for instance, by reducing or eliminating local taxes. The authority could suggest a bonus of say, ten cents per ton, and increase the offer by ten cents every week until one or more of the communities agreed to host the facility. The communities could well negotiate for improvements in the proposed facility—for a new access road to protect an area in which children play, for instance.

This approach also allows for private enterprise. In California, compensation is paid by Sunset Scavengers, the company collecting wastes from San Francisco, to the city of Mountain View, where the wastes are put in a sanitary landfill. The city also negotiated for the construction of a marina and other recreational facilities on the filled land. Payment was orginally about one dollar per ton, giving Mountain View citizens a very substantial tax benefit. Across the country, Massachusetts recently passed a law (largely because of efforts by several M.I.T. faculty members) to provide compensation to communities agreeing to accept treatment facilities for hazardous wastes.

I could cite many other cases in which such legislation would prove beneficial: reducing sulfur-oxide pollution from power plants, noise pollution from airports, and river pollution from hot or chemically laden discharges. The common feature of these approaches is that they seek to internalize externalities. They involve taxes that flow in a tightly controlled loop, providing compensation to affected communities and incentives for producers to reduce environmental pollution at the source. □

David Gordon Wilson is professor of mechanical engineering at M.I.T. This column is adapted from an article in the Dangerous Properties of Industrial Materials Report *(November/December 1980).*

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(embodied by pollution) can be corrected by yet another market. Yet some observers are already extolling, perhaps prematurely, the virtues of such a system. In a recent issue of *Harper's*, contributing editor William Tucker predicts a startling reduction in the government bureaucracy. Those who spend "countless thousands of hours deciding who should clean up what, when, and where could simply pack their bags and go home," he says. "All the decisions would be made where they belong—by the people who are going to bear the costs of deciding how to clean up."

But although this seems like a neat little system, its promise is clearly overstated. Markets in pollution rights can certainly be cost-effective in achieving a given set of standards on paper, but they do not guarantee results: the seller of a pollution credit has promised to abate *X* tons of pollutant *Y*, but the buyer has no incentive to see whether this is in fact done. Russell concedes this. "Controlled trading would not relax the need for pollution-control agencies," he says. They would still be needed "to monitor emissions and to punish the violators of permit terms." And, more importantly, government agencies (or other entities outside the market) would still be needed to establish the standards—to set the environmental goals that the system might then efficiently implement.

But a more worrisome result may be the "institutionalization" of pollution. A well-designed, smoothly functioning pollution-rights market might achieve economic equilibrium for a given "acceptable" pollutant level, but it would inherently provide barriers to stricter levels of control, or to elimination of that pollutant via technological replacement, should the need later be indicated. Such a transition, or quantum leap, could well elude the capabilities of the market mechanism alone, whether in products, by-products, or both.

But such concerns apply to the present system of environmental regulation as well, perhaps even more so, and the controlled-trading advocates simply propose a better solution, not necessarily an ultimate one. Even there, experts like Russell speak tentatively. "We should be careful not to expect too much," he says. "But many of the doubts and questions about controlled trading cannot be answered until we have tried it." ☐

Steven J. Marcus is managing editor of Technology Review.

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design in former times was due largely to autocratic leadership. He feels that success in our time can be achieved only by some unspecified new form of leadership, by someone filling the role attributed to Sixtus V, Catherine de Medici, and Charles I of England.

But Renaissance times are now so remote that it is difficult for anyone but a specialist historian to be dogmatic about cause and effect in cultural matters. Some of the architectural works mentioned by Mr. Pei progressed under sundry forms of government and resulted from collective wills, transcending the life of any individual autocrat. In addition, Charles I did nothing for the improvement of London, and the imagined Sir John Wood, promoter and employer of tame architects, did not exist. Agreed, wealth, ideas, and power are needed to build great cities, and some would say that leadership in ideas and power is too important to be left to professional architects. But the Western world is controlled by the democratic majority—studies of architectural values must be offered in our schools. Until an influential part of the total population becomes aware of the benefits and joys of a good civic and architectural environment, we can expect little progress.
Richard Bolton
Westmount, Canada

Mr. Bolton is an architect and urbanist who is chairman of the Architectural and Planning Commission of the city of Westmount. Mr. Pei responds:
I am pleased that Mr. Bolton agrees with my principal thesis that three elemental conditions are needed to build great cities. Cities are living organisms, and Rome, Paris, and London will continue to change and develop. What is the point then, of arguing whether the building of Rome should include Mussolini's era or the building of Paris should include works of Blondel and Gabriel? My concern is with people who by virtue of their authority and ideas gave form to their cities, for example, by superimposing a set of movement systems (Sixtus V) or by introducing the idea of the thrust of axio-extension (Le Notre and Haussmann). The contribution of Charles I to English urbanism should not be underestimated. The building of Covent Garden, Great Queen Street, and Lincoln's Inn Fields alone entitle him to the claim of having laid the important foundation stones for city design in England.

Since 1950 I have participated in the planning and design of many American cities. My experience allows me to share little of the optimism in Mr. Bolton's prescription for attaining good civic design merely by offering the public "studies of architectural values" and expecting architects alone to "lead the way."

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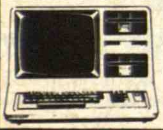

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